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The Effect of Skeletal Muscle Mass on Basal Metabolic Rate in College-age Males

By

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Submitted in Partial Fulfillment of the Requirements for the

Master of Science in Exercise Science Degree

Kinesiology Department

STATE UNIVERSITY OF NEW YORK COLLEGE AT CORTLAND

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### Abstract

There are many misconceptions within the fitness community. One such misconception is that an increase in muscle mass will have a large increase in basal metabolic rate, yet this may not be the best way for successful weight loss. The purpose of this study was to determine the strength of the correlation between skeletal muscle mass and basal metabolic rate. The hypothesis tested was that basal metabolic rate is strongly correlated with skeletal muscle mass. The participants were college-aged males ( $n = 17$ ). Skeletal muscle mass (SMM) was estimated using the skin-fold circumference model (SFCM):  $SMM (kg) = Ht (0.00744 CAG^2 + 0.00088 CTG^2 + 0.00441 CCG^2) + 2.4 \text{ sex} - 0.048 \text{ age} + \text{race} + 7.8$  (Lee et al., 2000). In the aforementioned equation, sex = 1 for male and 0 for female. and race = -2.0 for Asian, 1.1 for African American, and 0 for white or Hispanic. CAG, CTG, and CCG represent skinfold-corrected upperarm, thigh, and calf circumferences respectively.  $VO_2$  was measured and used to calculate basal metabolic rate (BMR);  $kcal = [(1.1 * RER) + 3.9] * VO_2 (L/min)$  (Weir, 1949). The mean skeletal muscle mass (SMM) for all subjects was 34.9 kg ( $SD = 6.25$ ). The mean resting  $VO_2$  for all subjects was 316.7 ml/min ( $SD = 58.0$ ). The mean basal metabolic rate (BMR) for all subjects was 2103 kcal/day ( $SD = 444$ ). BMR was plotted against SMM showing a positive linear relationship  $r^2 = 0.65$  and a high correlation value,  $r = 0.80$ . Based on the methods used and the statistical analysis of the data collected, results of this study suggest that an increase in SMM is associated with BMR. There was a 95% difference in kcals/day between the lowest and highest SMM value.

### **Acknowledgements**

I would like to thank my thesis advisor, Dr. James Hokanson. I would also like to thank Dr. Peter McGinnis and Dr. Philip Buckenmeyer. Without all of your support over the last few years, this would not have been possible. I would also like to thank the participants for their time and willingness to come into lab at such early hours. Without everyone involved, this would not have been possible.

## Table of Contents

	PAGE
Abstract .....	ii
Acknowledgments.....	iii
Table of Contents .....	iv
List of Tables .....	vi
List of Figures .....	vii
 Chapter	
1. Introduction.....	1
Purpose of Study .....	2
Research Hypothesis .....	2
Variables .....	2
Delimitations .....	2
Limitations .....	2
Assumptions.....	3
Operational Definitions.....	3
Significance of Study .....	4
2. Literature Review.....	5
Physical Activity and Obesity .....	5
Nutrient Intake and Physical Activity .....	8
Total Energy Expenditure, Energy Intake and PAL Effects on BMR .....	8
Basal Metabolic Rate .....	10
How Diet Effects Fat-Free Mass and BMR.....	10
Fat and Carbohydrate Metabolism During Exercise at Rest.....	12
Exercise During Weight Loss and BMR .....	13
BMR Among Different Sociological and Geographical Groups .....	15
Measuring Basal Metabolic Rate .....	17
Factors Effecting the Measurement of Basal Metabolic Rate .....	18
Summary .....	22
3. Materials and Methods.....	24
Participants.....	24
Instruments.....	24
Procedures.....	25
Assessment of Skeletal Muscle Mass and Basal Metabolic Rate .....	26
Statistical Analysis.....	28

4. Results .....	30
Results .....	28
Summary .....	52
5. Discussion, Conclusion, Recommendations .....	53
Discussion .....	53
Conclusion .....	60
Recommendation .....	60
References .....	61
Appendix	
A. Informed Consent .....	69
B. Arrival Script: Day One .....	71
C. Pre-Test Guidelines for Basal Metabolic Rate Assessment .....	72
D. Participant Basal Metabolic Rate Pre-Assessment Questionnaire and Agreement .....	73
E. Arrival Script: Day Two .....	74
F. Subject Physical Characteristics and Body-Composition Measurements .....	76
G. Matrix: Day One .....	77
H. Matrix: Day Two .....	78
I. Script .....	80
J. E-Mail to EXS 397 Students .....	81
K. IRB Approval Letter .....	82

## List of Tables

	PAGE
TABLE	
1. Anthropometric Measurement Sites .....	27
2. Subjects' Physical Characteristics and Body-Composition at Baseline .....	31
2A. SMM and BMR data .....	32
3. Subjects' Physiological Characteristics at Baseline .....	33
4. Comparison of BW, BMI and SMM and other studies .....	54
5. Comparison of BW and BMR between current and other studies .....	55
6. BMR of Participants with Fitness Preference .....	56
7. Comparison of the Highest SMM and BMR within each group .....	56
8. Comparison of participants with approximately same SMM .....	56
9. Comparison of Subjects 1 and 6 .....	58
10. Comparison of current study to Dolezal & Potteiger (1998) .....	59



## List of Figures

FIGURE		PAGE
1.	Day 1 and Day 2 Skeletal Muscle Mass .....	34
1A.	All Subjects and No Subject Eleven Skeletal Muscle Mass .....	35
2.	Day 1 and Day 2 Upper Arm Circumference .....	36
2A	Day 1 and Day 2 Upper Arm Skin fold .....	37
3	Graph Comparing SFCM and BWHM .....	38
4	Day 1 and Day 2 VO <sub>2</sub> Measurements .....	39
4A	All Subjects and No Subject Eleven VO <sub>2</sub> Measurement.....	40
5	Day 1 and Day 2 BMR Measurements .....	41
5A	All Subjects and No Subject Eleven BMR Measurements .....	42
6	Graph Showing Participant RER Over Full Twenty Minute Assessment .....	43
6A	Graph Showing Participant RER Over Middle Ten Minutes .....	44
7	Graph of Overall VO <sub>2</sub> Assessment for Control Participant .....	45
7A	Graph of Middle Ten Minutes of the VO <sub>2</sub> Assessment for Control Participant .....	46
8	Graph Shows the RER versus SMM.....	47
9	Change in BMR versus SMM in All Subjects .....	48
9A	Change in BMR versus SMM without Subject 11 .....	49
10	Change in Body Mass versus BMR .....	50
11	Change in VO <sub>2</sub> versus SMM.....	51
12	Graph Shows the RER Plotted against BMR.....	52

## **Chapter 1**

### **Introduction**

The effects of obesity and the negative health consequences that accompany it are well documented Pi-Suyner (1993), Sturm and Wells (2001). The costs of obesity are reaching magnitudes that may overwhelm healthcare systems throughout the world (Malkova et al., 2006). To curb this epidemic, diet programs have been developed but many question whether or not dieting alone will improve one's health. According to Kramer et al. (1989), obesity treatments that rely heavily on dieting alone usually result in poor long-term outcomes. People that mainly use dieting to decrease obesity usually regain most of the weight lost within 2-3 years (Kramer et al., 1989). Dieting alone may have discouraging results; however, the addition of exercise as a treatment has become increasingly emphasized. An increase in exercise may also result in an increase in daily energy expenditure (EE) (Malkova et al., 2006).

Energy expenditure (EE) has been studied for many years. According to Cunliffe and Stiegler (2006), there has been ongoing research by organizations such as the World Health Organization (WHO), Food and Agriculture Organization (FAO) and the United Nations University (UNU), to estimate daily energy requirements. Cunliffe and Stiegler (2006) continued to look into total energy expenditure. Their research investigated how total energy expenditure and daily physical activity levels pertain to and affect basal metabolic rate (BMR). BMR represents the minimum cost of living and is commonly measured by rate of O<sub>2</sub> consumption (Hulbert & Else, 1003).

One misconception of BMR is that an increase in skeletal muscle mass has a significant effect on BMR. This can be observed by measuring BMR to determine which

body type, low or high skeletal muscle mass, utilizes more calories at rest. The question addressed in the current study was: does a greater skeletal muscle mass significantly increase basal metabolic rate? This information is pertinent because it could determine how those looking to lose weight, become a better athlete, or improve overall health should train. For an athlete it is important to maintain an increased BMR by maintaining a high fat free mass (FFM) level. A low BMR, as a result of low FFM may result in unwanted weight gains (Cunliffe & Stiegler, 2006).

### **Purpose of Study**

The purpose of this study was to determine the strength of the correlation between skeletal muscle mass and basal metabolic rate.

### **Research Hypothesis**

Basal metabolic rate is strongly ( $r \geq 0.7$ ) correlated with greater skeletal muscle mass.

### **Variables**

The independent variable was skeletal muscle mass, and the dependent variable was basal metabolic rate.

### **Delimitations**

Delimitations imposed by the researcher included:

1. Selecting only male subject
2. Subjects regularly participate in fitness activities.
3. Subjects were college-age

### **Limitations**

Limitations of this study included:

1. Skeletal muscle mass was estimated using an equation developed by Lee et al. (2000).

2. True skeletal muscle mass was not directly measured.
3. Basal metabolic rate was estimated using an equation developed by Weir (1949).
4. Hydrostatic weighing was not used because it was not assembled at time of study.
5. One group is labeled “Half Participation” due to a lack of calibration tanks for BMR assessment.

### **Assumptions**

The following assumptions were made for this study:

1. Subjects were accurate when answering questions
2. Instruments used for data collection were valid and reliable
3. All subjects were healthy unless otherwise stated by participant.
4. The researcher accurately calculated the skeletal muscle mass prediction equation.

### **Operational Definitions**

1. Basal Metabolic Rate (BMR) – The lowest rate of body metabolism (energy use) that can sustain life, measured after an overnight sleep in a laboratory under optimal conditions of quiet, rest, and relation after fasting (Wilmore, Costill, & Kenney, 2008).
2. Body Mass Index (BMI) – BMI is a measurement of body over-weight or obesity determined by dividing weight (in kilograms) by height (in meters) squared. BMI is highly correlated with body composition (Wilmore, Costill, & Kenney, 2008).
3. Breeze Suite Software – Diagnostic testing software that combines gas exchange and pulmonary function testing into one application (“Medgraphics cardiorespiratory diagnostics”)
4. Fat Free Mass (FFM) – The mass (weight) of the body that is not fat, including muscle, bone, skin, and organs (Wilmore, Costill, & Kenney, 2008).

5. Indirect Calorimetry – A method of estimating energy expenditure by measuring respiratory gases (Wilmore, Costill, & Kenney, 2008).
6. Spirometry – measures the volumes of air inspired and expired and therefore changes in lung volume (Wilmore, Costill, & Kenney, 2008).
7. Respiratory Exchange Ratio (RER) –The ratio of carbon dioxide expired to oxygen consumed at the level of the lungs ( $VCO_2/VO_2$ ).
8. Stadiometer – Device used to measure height and weight.
9. Steady-state conditions – A coefficient of variation of <10% in  $VO_2$  and  $VCO_2$  over a set time period (Compher et al., 2006).
10.  $VO_2$  –The volume of oxygen consumed per minute.
11.  $VCO_2$  –The volume of carbon dioxide produced per minute.

### **Significance of Study**

Although many people believe that an increase in muscle mass will significantly increase basal metabolic rate, this may not be the only way for successful weight loss. The purpose of this study is to determine if skeletal muscle mass is related to basal metabolic rate. High skeletal muscle mass and low skeletal muscle mass values will be compared in individuals to determine which body type generates higher basal metabolic rate values. Johnstone et al., (2005), suggest that fat free mass and fat mass both significantly contribute to BMR. Determining which body type, low or high skeletal muscle mass, generates a higher basal metabolic rate value can help provide optimum results from the dieting and exercise regiments that are being recommended by professionals to help curb obesity.

## **Chapter 2**

### **Literature Review**

The purpose of this study was to determine if skeletal muscle mass is related to basal metabolic rate. This information is pertinent because it could determine how those looking to lose weight, become a better athlete, or improve overall health, should train. It is important to maintain an increased BMR by maintaining a high FFM level. High FFM is good for athletes and may be due to high BMR. A low BMR, as a result of low FFM may result in unwanted weight gains (Cunliffe & Stiegler, 2006). Topics that will be discussed in this section include: the effects physical activity has on obesity and energy expenditure, diet and physical activity, basal metabolic rate, exercise during weight loss, different activities that affect metabolism (i.e. resistance exercise, aerobic exercise, and/or combination training), and methods of BMR measurement.

#### **Physical Activity and Obesity**

Height, weight, and body composition may vary according to physical development among individuals and children. The adult definition of obesity is also not consistent with the definition of obesity in children in relation to body mass index (BMI). BMI is higher in adults than children depending on age and gender. (Steinbeck, 2001). It is for these reasons that BMI values are defined as a percentile or standard deviation score (Hammer et al., 1991). The children can be assessed based on a percentile score in which researchers can state how far from zero the child's BMI is. The importance of BMI is that it has helped relate childhood obesity to adult obesity.

According to Steinbeck (2001), a definition for physical activity is not asleep or sedentary. It includes any activity that occurs in day-to-day living such as sports or basic

movement. Physical activity will vary in frequency, intensity, and time and may consist of resistance or aerobic activity.

The developmental stage of a child may directly affect the type of physical activity. The spontaneous physical activity shown by children, which is often discouraged by adults, should be encouraged to help expend energy. This spontaneous physical activity or movement in general, can be altered to help expend more or less energy. In order to decrease a sedentary lifestyle, an increase in physical activity levels is suggested (Steinbeck, 2001). Malkova (2006) observed the spontaneous activity responses to exercise in both males and females. The study concluded that there was no difference of spontaneous activity energy expenditure (SAEE) between males and females. Body mass (BM) was maintained in males but not females due to an increase in energy intake (EI) (Malkova et.al, 2006).

Various observational studies support stop-start activity for young children (Steinbeck, 2001). This includes spending about half of the time being sedentary and 10% of the time being involved in vigorous play. Raitakari et al., (1997) observed cardiovascular disease in Akerblom et al., (1991). Higher physical activity levels appeared more in males than female (Raitakari et al., 1997). The intensity of this physical activity is suggested to be important, even in the pre-pubescent age groups (Moore et al., 1991).

Family directly affects physical activity. According to Fogelholm et al. (1991), children's activity levels are higher than that of their parents. If a child has an active mother, that child is twice as likely to be active as a child with an inactive mother. If a child has an active father, that child is three and a half times more likely to be active than a child with an inactive father. This observation is a result of parental modeling, support for activity, and genetic effects. Physical activity during adolescence may affect how healthy someone is as

an adult. A follow up on the Young and Finns study, which was conducted by Marti et al. (1989), showed that physical activity during the adolescent stage is inversely related to body fat percentages during the early years of adulthood. In the Amsterdam Growth and Health Study, children that were less active had elevated fat skinfolds as an adult (Twisk et al., 1997).

Children who are obese are not as likely to participate in physical activity, whether it is vigorous or moderate exercise (Eberhardt et al., 1999). Field tests and laboratory tests have been utilized to assess aerobic fitness. Obese children tend to be less fit than their friends or family (Eberhardt et al., 1999). There is an increase in upper body static strength and power due to an increase in lean body mass. Although their upper body performance is increased, they experience difficulty in lower body activities such as walking, running, and flexibility. Obese children also expend more energy when performing lower body activity than a person with a lower body weight.

Metabolism varies between adults and children. Fat is a more significant contributor than CHO to EE in children, although it varies according to gender. Gender differences for metabolism of fat and CHO relate to different sex hormones released in men and women. When estrogen is released in women, metabolic capacity for CHO and fat is increased (D'Eon et al., 2002). Although it has been supported that hormones may affect substrate metabolism, no studies show effects on metabolism prior to puberty (Aucouturier et al., 2008). Children tend to have higher respiratory rates and notable differences in muscle contraction when compared with adults, which occurs in response to an increased exertion observed in children (Aucouturier et al., 2008).



The term “mode of exercise” refers to the type of exercise being performed. It is important to define the mode of exercise because many exercises can be performed in many different ways. Exercising can be classified as either continuous or intermittent depending on their work to rest ratios. Some researchers believe that fat and CHO contribute to EE similarly between continuous sub-maximal exercise and intermittent high intensity exercise (Aucouturier et al., 2008). When children participate in intermittent, short, and intense exercise, fat is utilized similarly to adults that perform lower intensity, continuous exercise.

### **Nutrient Intake and Physical Activity**

The equation of energy balance includes two very important aspects: nutrient intake and physical activity (PA). If nutrient intake is higher than energy requirements followed by low levels of PA, possible weight gain may occur in childhood. Human physiology has evolved under many different environmental conditions, all of which have different effects on humans. In past environments, hunting preceded eating. After hunting, there was a reduction in PA after eating. In our current society, exercise is used as a means to counteract over-nutrition (Steinbeck, 2001). In order to help control the obesity epidemic, it is essential that an acceptance of PA in children must be considered normal (Steinbeck, 2001). Also, according to Steinbeck (2001), eating needs to become more restricted with planned intake of “treat” foods.

### **Total Energy Expenditure, Energy Intake and Physical Activity Level Effects on BMR**

According to Kurpad et al., (2006), the product of BMR and physical activity level (PAL), is total daily energy expenditure (TEE). This supports that there is a direct correlation between the following factors of BMR, physical activity levels and total energy expenditure. Thus both TEE and PAL are very important when measuring BMR.

FAO/WHO/UNU (2004), states that physical activity, when combined with a healthy diet and non-use of drugs, helps to prevent diseases such as type II diabetes, hypertension, and cardiovascular disease which may be caused by obesity. The World Health Organization recommends individuals to reduce fat, salt, and sugar food intake and increase physical activity in order to combat the obesity epidemic (Kurpad et al, 2006).

In Sweden, body weight (BW), body mass index (BMI), and overweight in both children and adults has increased (Bratteby et al, 2005). Although no real cause can be determined, an excess caloric intake and decreased energy expenditure (EE) might possibly be what is causing the energy imbalance. The modern lifestyle that includes an increase in overeating as well as an increase in sedentary lifestyles intensifies the preponderance of obesity. Although there may be controversy as to which factor plays a bigger role, both factors must be considered (Prentice & Jebb, 1995). Bratteby et al. (2005) observed a positive correlation between physical activity and energy expenditure during adolescence and early adulthood between two groups; gender and socioeconomic regions. There were many different factors that may have affected the results. Physical characteristics, physical activity habits, energy expenditure and physical activity levels, corollaries between TEE, and PAL, were among the topics discussed. The main finding of Bratteby et al. (2005) was that both males and females of both age groups had high PAL and EE. There was also a connection between the high PAL coupled with minimal time spent sitting throughout the day (Bratteby et al., 2005). Overall, this study suggests that physical activity, energy expenditure, and energy intake may vary based on specific differences among members of similar groups.

## **Basal Metabolic Rate**

The measurement of BMR was originally developed as a concept to observe and compare the metabolic rate of animals (Lutz, 2002). It was first used on humans as a clinical method to determine thyroid status. Antoine Lavoisier was the first to measure BMR by animal respiration and how its rate can be affected in a post-absorptive state (Lutz, 2002). Eventually BMR came to represent the minimum cost of living and is commonly measured by rate of O<sub>2</sub> consumption (Hulbert & Else, 2003).

BMR, as discussed later, can be measured using different methods. Direct and indirect calorimetry are two ways that can be used to measure energy expenditure. Direct calorimetry is used when trying to measure the body's heat production. Indirect calorimetry is used when measuring expended energy by calculating respiratory exchange of O<sub>2</sub> and CO<sub>2</sub> (Wilmore, Costill, & Kenney, 2008).

## **How Diet Affects Fat-Free Mass and BMR**

Cunliffe & Stiegler (2006) examined BMR and how diet and fat-free mass are correlated. While a majority of people do not succeed in weight loss programs by either failing to maintain weight loss or maintaining healthy diet. The inability or failure to change a lifestyle of high dietary intake and low physical activity may result in improper weight maintenance, which antagonizes a reduction in BMR (Cunliffe & Stiegler, 2006).

BMR is the primary source of metabolic activity consisting of 60-70% of TEE. A major factor affecting the magnitude of an individual's metabolic activity at rest is fat-free mass (FFM) (Tataranni et al., 2003, Ravussin et al., 1988, Seidell et al., 1992, Muller et al., 2002). FFM is made up of muscle and organs which are highly metabolic, whereas bone and connective tissue are considered to have a low metabolic rate (Muller et al., 2002). As a

result of this, any diet or exercise interventions, which enable the maintenance or enhancement of FFM, may affect the body's energy balance significantly. Other physiological factors such as thyroid hormones, leptin levels, and sympathetic nervous system activity are considered to affect BMR (Cunliffe & Stiegler, 2006).

The main objective of losing weight is to reduce fat mass, which may result in an unintentional loss in lean body mass. When fat mass is reduced, this leads to a decreased possibility of developing a risk of cardiovascular disease (CVD) (Cunliffe & Stiegler, 2006). Some diet interventions include increased loss of FFM. Such interventions may result in reducing CVD risk factors or maintenance of long-term weight loss. However to preserve the FFM there must be a maximized content of fatty tissue. Van Aggel-Leijssen et al. (2002) and Torbay et al. (2002) showed that decreases in BMR may not be accompanied by FFM loss and changes in BMR may result may be due to changes in muscle tissue. According to Cunliffe and Stiegler (2006), many interventional studies have been completed throughout the past two decades. Dietary interventions have been shown to impact FFM and BMR. Diets will be discussed in this review that are energy restrictive, high carbohydrate diets, low-fat diets, and high protein diets.

When weight is lost due to a restriction in diet, a decline in BMR can be a result. Physiological factors and the loss of FFM also contribute to the decline in RMR (i.e. thyroid, leptin, sympathetic nervous system). Due to these physiological factors and modifications to ones diet there may be a chance to stop the fall of BMR. Body fat levels and ability to control appetite can be linked to the hormone, leptin. This hormone has been linked to body fat levels and appetite control (Katch, McArdle, & Katch, 2006). The secretion of leptin is reduced when the amount of adipose tissue is decreased. Leptin levels can be used as a

method of predicting BMR. When losing weight, it is important to maintain leptin levels to maintain weight loss. Leptin levels can also be affected by carbohydrate (CHO) consumption suggesting that there is an impact of such a macronutrient on diet and EE (Cunliffe & Stiegler, 2006). A decline in BMR can also be prevented by attempting to maintain current FFM levels.

One popular method for reducing bodyweight is to change the carbohydrate (CHO) to fat ratio of the diet. As a result of a high CHO and low fat diet, rapid decrease in bodyweight may occur. This rapid decrease occurs when a considerable amount of fat is removed during intake, which may also include reductions in FFM. Researchers believe that some diets that include low glycemic index foods would increase the amount of BW lost. Foods like potatoes, breads, etc. are high glycemic index foods. These high glycemic index foods may increase body fat, resulting in weight gain. Although diets that are high in CHO and low in fat are recommended, they do not necessarily mean that the greatest possible body weight loss will occur. (Cunliffe & Stiegler, 2006).

Some diets include replacing some CHO in a high protein diet. Researchers believe that this method may result in a change body composition in a more desirable way, compared to the high CHO or low fat diets previously mentioned. Low calorie diets that are high in protein may improve weight loss for people who are overweight. An increase in protein may preserve BMR due to sustained lean tissue (Cunliffe & Stiegler, 2006).

### **Fat and Carbohydrate Metabolism during Exercise and Rest**

Fats and carbohydrates (CHO) are the primary source of energy expended during exercise and at rest. Several factors are associated with CHO and fat utilization while exercising. These factors include exercise intensity, age, exercise duration, type/mode of

exercise, and training. According to Brooks and Mercier (1994), as exercise intensity is increased there is a shift from utilization of fat as a source of energy to CHO. CHO does not provide as much energy per gram as fat, therefore, less oxygen is needed to oxidize carbohydrates than fat. This means a respiratory exchange ratio (RER) for CHO is higher than for fats. When the body is at rest, the primary source of energy is fat. A resting RER should range from 0.71 - 0.80 (Wilmore, Costill & Kenney, 2008).

### **Exercise during Weight Loss and BMR**

Physical activity is an important factor in weight loss. An increase in PA, without modifying diet, might be the best way to observe how body composition, weight and BMR are affected. This increase in PA and no modification to energy intake may result in decreasing body fat because there is less energy being taken in than is expended by the body's metabolism.

Although PA increases energy expended, there are additional methods to increase BMR. It is important to understand that retaining lean body mass may be a result of weight loss due to exercise. The largest impact that exercise can have on BMR occurs when skeletal growth is initiated which underscores the connection between lean muscle mass and BMR (Ryan, 2000).

Researchers have also seen an increase in EE after exercise. This increases metabolic rate for just a short term (~24 hours) (Maehlum et al., 1986). This rise in post-exercise metabolism may occur depending on exercise intensity (Borsheim & Bahr, 2003). A low intensity workout is less likely to have a noticeable increase in post-exercise metabolism, but small changes may occur. There is a difference between trained and untrained individuals. Trained individuals will notice that BMR will return to baseline much quicker than in an

untrained individual. There has been little research on the direct correlation between BMR and exercise training although it does seem apparent. However, frequency, intensity, and duration of exercise can be factors related to body composition as a result of exercise intervention (Cunliffe & Stiegler, 2006). Results may vary between aerobic training, resistance training, or a combination of both.

Aerobic exercise can vary in frequency, intensity, time and duration. Exercise intensity is an important factor in determining whether the body uses fat or CHO as an energy source. During low to moderate levels of PA, fat is the primary source of energy. As exercise intensity increases, fat oxidation slowly decreases. There are many factors that contribute to selection of an aerobic program. Since weight loss is usually the goal of obese or overweight patients, high intensity training is out of question due to low aerobic fitness and lack of capability to withstand high intensity exercise. Most weight loss tools are traditionally based on low-to-moderate exercise intensity (Cunliffe & Stiegler, 2006). Researchers have used training programs to study the effect of exercise on BMR. Cunliffe & Stiegler (2006), suggested that there may be a slight decrease in body weight and FFM as a result of extended, sub-maximal exercise.

Aerobic exercise can also be combined with resistance exercise. During resistance exercise, there is a lower metabolic demand than aerobic exercise. This is due to the relatively small muscle mass that is used during resistance exercise. Walberg (1989) suggests that weight training can increase muscle. However, when compared to aerobic exercise, it is less likely to result in an increase in FFM and RMR or a decrease in body fat. Other studies have shown an elevation in BMR in resistance-trained athletes whereas there was a decrease in BMR in subjects that participated in a combination of aerobic and

resistance exercise programs. It is important for an exercise program to show a successful reduction in body fat and an increase in fat-free mass. In order for these changes to occur, several exercise sessions must be completed. While any kind of exercise would be beneficial for different aspects, an exercise cannot be analyzed simply on its ability to increase FFM alone, because an increase in BMR may not be likely (Cunliffe & Stiegler, 2006).

Dolezal and Potteiger (1998) assessed thirty physically active healthy men with a mean age of 20 years old, who were assigned to participate in a ten-week training program. Each group was assigned to one of the following groups: endurance trained (ET), resistance trained (RT), and a group that was trained with a combination of resistance and endurance trained (CT). The BMR of participants was measured before and after the 10-week training program of their specific group. The results of this study found that the RT group had a pre- and post-BMR of 1818 kcal/day ( $SD = 231$ ) to 1920 kcal/day ( $SD = 227$ ) respectively. The ET group had a pre- and post-BMR of 1727 kcal/day ( $SD = 132$ ) to 1678 kcal/day ( $SD = 159$ ) respectively. The CT group had a pre- and post-BMR of 1780 kcal/day ( $SD = 230$ ) to 1867 kcal/day ( $SD = 234$ ), respectively (Dolezal & Potteiger, 1998). The pre- and post-assessment of BMR was significantly increased in the RT and CT groups but not for the ET group (Dolezal & Potteiger, 1998).

### **BMR Among Different Sociological and Geographical Groups**

BMR may not only be affected by factors such as exercise, diet, age, or gender but it may also be affected by ethnicity or geographical location. BMR can be measured by predicted equations derived from Schofield (1985) in which there was no specific population measured (Anjos et al., 2007). Some researchers believe that these predicted equations tend to overestimate BMR in populations from the tropics and temperate regions (Anjos et al.,



2007. In the 1920's Brazilians were studied to observe the effect that climate had on BMR, and was it lower than the predicted equations suggested (Almeida, 1919). This idea that BMR was lower in Brazilian populations living in the tropics was based on studies that used both measured BMR and estimated BMR (Anjos et al., 2007). Anjos et al. (2007) used the Schofield equation, Harris and Benedict equation, and the Henry and Rees equations to assess whether BMR would change in Brazilians living in the Sonoran desert and the South Western USA. The results of the study indeed showed that estimations of BMR in Brazilians were overestimated in both men and women. However, when body composition is considered, BMR of populations living in the tropics is similar to BMR of people living elsewhere (Anjos et al, 2007). This study supports research that there are inconsistencies of the predictive BMR equations as well as inaccuracies.

In a longitudinal study by Buscemi et al. (2005), a correlation between a relatively low BMR and body weight gain was observed in Caucasian Italians. The results of the study showed that a low BMR was indeed associated with weight gain in Caucasian Italians. Instead of using the predictive equations, this study used body composition, which was measured by bioelectric impedance, fat mass percentage, and indirect calorimetry.

Minghelli et al. (1990) measured BMR of 20 young Gambian men and 16 European men. The Gambian men averaged a body weight of 60.8 kg ( $SD = 1.4\text{kg}$ ), while the European men had an average body weight of 66.9kg ( $SD = 1.9\text{kg}$ ) (Minghelli et al., 1990). The total energy expenditure was lower in Gambian men, 2047 kcal/day ( $SD = 46$ ), than in European men, 2635 kcal/day ( $SD = 74$ )

## Measuring Basal Metabolic Rate

The measurement of BMR was first done by Harris and Benedict (1918). Several decades later Schofield and colleagues developed the most recent predictive equations (Schofield, 1985). These equations include six equations where BMR can be predicted by weight, age or gender. These equations however do not take fat mass or fat-free mass into account and are only predictive.

Prediction methods are not the only way to measure BMR. BMR can be measured in several different ways and can be very difficult. Specialized equipment may be used, which may not easily be accessible, or practical, resulting in consuming a lot of time. Some researchers use the aforementioned prediction or estimation equations and continue to try to improve them.

Duncan et al. (2006) studied ways to improve the predictability of BMR by using additional anthropometric measures. This method is conducted after the subject completes an overnight fast and there is no caffeine intake or tobacco products before the measures are taken. Height and weight measurements are also taken and BMR is measured by using indirect calorimetry (Duncan et al., 2006). According to the results of the study, the correlation between the previously discussed measured BMR and the Schofield predicted BMR was strong ( $p = 0.001$ ;  $R^2=0.763$ ). However, the results showed that there was an overestimation of BMR for the predicted equations (Duncan et al., 2006).

The study discussed in Duncan et al. (2006) also used body composition to measure BMR by using a Bod-Pod. The results of this method show that there is a strong positive correlation between BMR and fat-free mass ( $p < 0.001$ ), and BMR and fat mass ( $p < 0.001$ ) but BMR was negatively correlated with age ( $p < 0.01$ ). However, there was no significant

relationship between the accuracy of the predicted equation method and the body composition method.

Anthropometric measurements can also be used to predict BMR. This method requires measurements of body fat by using skinfold thickness. Skin-folds are taken at four sites: triceps, bicep, suprailiac, and subscapular (Duncan et al., 2006). The previously mentioned study aims to improve methods of measuring predicted BMR. The best method according to Duncan et al. (2006) is the use of anthropometry as well Schofield's predicted equations. Utilizing anthropometry as a prediction of BMR improved the reliability as well as accuracy of results. PA can be measured by direct observation of heart rate, while accelerometers can be used to monitor the doubly-labeled water technique/BMR technique (Steinbeck, 2001). According to Compher et al. (2006), if the BMR measurement procedure is conducted properly, the result of the measurement should be more accurate than the prediction equations.

The American Dietetic Association has identified a need for research to determine if indirect calorimetry is the most effective method for measuring BMR (Compher et al., 2006). More importantly, Compher et al. (2006) reviews the process that test administrators should follow when conducting BMR tests by way of indirect calorimetry.

### **Factors Effecting the Measurement of Basal Metabolic Rate**

The first variable that Compher et al. (2006) researched was the effect that different fasting time periods may have on BMR measurement and what the most effective fasting period would be. According to Hill and Reed (1996) a fasting period of at least five hours would be necessary for unaffected BMR measurement. It has been shown that there should be no use of nicotine or caffeine prior to testing BMR. According to Perkins et al. (1990)

and Audrain et al. (1991), nicotine can affect BMR within 10 minutes of exposure, therefore it is suggested that there should be no nicotine consumption for at least two hours prior to measuring BMR (Compher et al. 2006).

Koot and Deurenberg (1995) studied the effects of caffeine on BMR. The results suggest that 3 hours after exposure an increase in metabolic rate was sustained. Although there is no definite time line for metabolic rate to return to resting levels after consumption of caffeine, Bracco et al. (1995) suggest that abstinence from caffeine for a minimum of 12 hours results in metabolic rate returning to resting levels.

Prior to measuring BMR, a rest period must be observed in order to ensure accuracy. If an individual performs any physical activity before BMR measurement, the results of the test may show an increased BMR. However, low levels of regular physical activity prior to testing may not effect BMR measurements when provided adequate rest time. Therefore, a rest period is necessary. A common question among researchers involves the appropriate length of a rest period before an accurate BMR measurement may be obtained. Fredrix et al. (1990) and Turley et al. (1993) measured BMR in a group of 10 people with an average age of 25 years old. They found that when the group got out of bed and completed routine physical activities such as putting shoes and clothes on and driving to the test site, they had similar BMR measurements as when they slept over night at the testing center. Although further research is needed to determine exact rest period, studies such as Igawa et al. (2002), Kwashiwazaki et al. (1990), and Ceulmans et al. (1992) suggest that a rest period of 10-20 minutes is a sufficient period prior to testing.

When physical activity increases, energy expenditure also increases proportionally depending upon the amount of work performed. Burleson et al. (1998), Freeman-Akabas et

al. (1985), and Williams and Plowman (1991), recommended that two hours of rest time is needed for metabolic rate to return to a resting state after moderate aerobic physical activity. Gillette et al. (1994), recommended a rest period of 14 hours after vigorous resistance training.

It has been shown that body position can be associated with effecting BMR. Since different postures may increase BMR, it is important to ensure each individual is comfortable with the BMR positioning. According to Levine (2000), individuals sitting in an upright position, although motionless, had a higher RMR than those in a supine position.

Compher et al. (2006) suggests that room temperature should be between 68°F and 77°F. Other environmental factors that may affect BMR to are ambient noise and lighting. There is insufficient research on the effects of noise and lighting among healthy individuals, however, Feurer and Mullen (1986) and McClave et al. (1992) suggest a quiet room and mild lighting is ideal when measuring BMR in critical care patients. These suggested room conditions can be used for healthy individuals also.

Gas collection devices are important to determining BMR. Collection devices such as facemasks, mouthpieces, nose clips, and canopies can be used for indirect calorimetry (Compher et al, 2006). Studies such as Ceulemanns et al. (1992), Isbell et al. (1991), Askanazi et al. (1980), and McAnena et al. (1986) suggest that when there is no air leak present in the aforementioned devices, BMR measures are similar. Forse (1993) measured BMR using a facemask and a mouthpiece and then compared to the results of a canopy. The results showed that the facemask and mouthpiece were 7% and 9% higher respectively than canopy measurements.

When obtaining a BMR, steady state conditions must be identified. In a review by Compher et al. (2006), steady-state conditions are identified by the variation of degree between  $\text{VO}_2$  and  $\text{VCO}_2$  over a certain time period. Steady state conditions are important because they decrease the chance that measurement could be affected. (Fredrix et al., 1990, Ceulemans et al., 1992, Isbell et al., 1991). Isbell et al. (1991) and Horner et al. (2001) suggest a reliable measurement of BMR can be obtained when the first five minutes of data and the last five minutes of data have a coefficient of variation of  $< 10\%$ .

Research has shown that a respiratory exchange ratio (RER) should be applied when interpreting BMR measurement results (Compher et al., 2006). RER is determined by the ratio of  $\text{VO}_2$  and  $\text{VCO}_2$ . An ideal RER range in humans is approximately 0.7 to 1.0. RER may be affected by fasting or eating large amounts of food prior to measurement. Romijn et al (1990) found that after 16 hours of fasting individual RER values ranged from 0.72 to 0.80 and may be less than 0.72 as fasting time increases. While fasting affects metabolism RER, food consumption does also. Depending on the size of the meal, RER may increase. Saltzman et al. (1996) found that after 60 minutes of meal consumption RER average was around 0.86. Over consumption of food may raise RER above 1.0. Surina et al. (1993) found that 10 minutes after consuming 1200 kcal of a high-fat and high-carbohydrate meal, the average RER value among individuals tested was approximately  $.98 \pm .04$  to  $1 \pm .04$ . Respiratory changes may also have a negative effect on BMR measurement. In a study by McCamish et al. (1981), there was an air leak in the equipment that resulted in RER values ranging from 0.32 to 1.02. Brandi et al. (1989) also had ventilator settings unexpectedly change which resulted in RER values  $> 1$  with hyperventilation and  $< 0.73$  with hypoventilation.

## Summary

The effects of obesity and the negative health consequences that accompany it are very well documented by Pi-Suyner (1993) and Sturm and Well (2001). The costs of obesity, as well as other diseases, are reaching magnitudes that may overwhelm healthcare systems throughout the world (Malkova et al., 2006). To curb this epidemic, many diet programs have been experimented with and, although popular, are questioned by many whether or not dieting alone will improve one's health. According to Kramer et al. (1989), obesity treatments that rely heavily on dieting alone usually result in poor long-term outcomes. People that mainly use dieting to decrease obesity usually regain most of the weight lost within 2-3 years (Kramer et al., 1989). Dieting alone may have discouraging results; however, using exercise as a treatment has become increasingly emphasized. An increase in exercise may result in an increase in daily energy expenditure (EE) (Malkova et al., 2006).

Energy expenditure has been a popular topic that has been studied for many years. There has been ongoing research by organizations such as the World Health Organization (WHO), Food and Agriculture Organization (FAO) and the United Nations University (UNU), to estimate daily energy requirements. Researchers such as Cunliffe and Stiegler (2006) continue to look into total energy expenditure. The research investigates how total energy expenditure and daily physical activity levels pertain to and affect basal metabolic rate (BMR). BMR represents the “minimum cost of living” and is commonly measured by rate of O<sub>2</sub> consumption (Hulbert & Else, 2003). One misconception of BMR that will be studied is whether muscle burns more than fat and the effect had on BMR by predicted skeletal muscle mass. This can be observed by measuring BMR and skeletal muscle mass to

see which body type burns more calories at rest. This information is pertinent because it could determine how those looking to lose weight, become a better athlete, or improve overall health will train.



## **Chapter 3**

### **Materials and Methods**

The purpose of this study was to determine the strength of the correlation between skeletal muscle mass and basal metabolic rate. The hypothesis was that basal metabolic rate is strongly correlated with skeletal muscle mass. This chapter includes information such as the participants, instruments, procedures, and assessment of BMR and skeletal muscle mass information.

#### **Participants**

Male SUNY Cortland students, ages 18-22 and with a body mass index (BMI) <30 were asked to participate in the study. There were two meetings with each participant. Prior to participating in the research study, the participants were asked to read and sign an informed consent form (APPENDIX A). Numbers were assigned to the participants to keep their name and information confidential. During recruitment, it was assumed that each subject had passed a physical examination by their general practitioner and was deemed medically stable unless otherwise stated. Approval by the Institutional Review Board at SUNY Cortland was required prior to any data collection pertaining to this study (APPENDIX K).

#### **Instruments**

The subjects' height (cm) and weight (kg) were obtained using a stadiometer (Detecto Medic). Skin-fold thicknesses were measured on the right side of the body using a Lange caliper (Country Technology Inc, Gay Mills, WI). Circumferences were measured with a flexible standard measuring tape as reported by Lohman et al., (1988). An open flow system without a mask was linked to a Med Graphics Metabolic Cart to measure gas exchange ratios. The Metabolic Cart was connected to a computer using Breeze Suite 6.4.1 software.

This software was used to calculate gas exchange ratios. The researcher then used the data collected to calculate kilocalories (kcal/min) by using the equation of Weir (Weir, 1949).

## **Procedures**

Recruitment of participants began by sending an e-mail to Dr. Hokanson and Dr. Buckenmeyer's Exercise Physiology students (typically 120 students). There was also a script (APPENDIX I), similar to the e-mail (APPENDIX J), read aloud while these students were in the Exercise Physiology Lab. In the e-mail and script there was a report date and time for an informational meeting. The researcher also scheduled a time with the Exercise Physiology Graduate Assistants, to meet with participants in their EXS 397 Lab for sign up. Typically, body composition and metabolic rate are laboratory experiences offered in these classes. Dr. Hokanson and Dr. Buckenmeyer agreed to offer an incentive for students who participated in data collection. They were offered, if they chose to participate, a lab grade of 10 points. Students who did not participate were asked to write a two page peer review paper abstract that related BMR and muscle mass. This gave students not involved in the study an opportunity to get 10 additional laboratory points.

Data were collected over two days. Each participant was given a number upon arrival. This ensured confidentiality for the participants involved. Each participant was asked to wear appropriate clothing (i.e., shorts and a short sleeved shirt) that allowed for measurements to be taken directly on the skin at the given sites for skinfold as well as circumference measurements. Participants arrived at the facility for BMR and skeletal muscle mass assessments on two separate days. For both data collection days, the procedures listed below were followed such that both assessments were completed.

### **Assessment of Skeletal Muscle Mass and Basal Metabolic Rate**

Upon arrival of the subject, the researcher reviewed the Pre-Test Guidelines for Basal Metabolic Rate Assessment (APPENDIX C) with the participant. If the participant failed to meet these guidelines before they arrived for the day, they were asked to return a different day. If the participant failed to meet the following guidelines more than once, they were dropped from the study. No subjects failed to meet the guidelines. The guidelines required the following of the participant:

1. No physical activity 12 hours prior to testing.
2. Minimum of 10 hour fasting period.
3. No nicotine 12 hours prior to testing.
4. No caffeine 12 hours prior to testing.
5. The morning of assessment, subject must urinate at least once prior to testing.
6. Subject must show up between the hours of 6:00-8:30 am on the scheduled date of test.
7. Subject rested for 20 minute immediately prior to testing.

Prior to assessing skeletal muscle mass, the researcher read a script (APPENDIX B) to each participant and described the data collection procedures. Each subject was also asked to read and answer all questions on the Participant Basal Metabolic Rate Pre-Assessment Questionnaire and Agreement (APPENDIX D). The researcher then prepared each participant for skeletal muscle mass measurements. Height and weight were measured first. Height was measured to the nearest 0.5 cm. Subjects wore light clothing and their weight was recorded to the nearest 1/10 kilogram. Circumferences were then measured at three sites with a non-elastic tape measure. These sites included the arm, thigh, and calf. Skinfolds were also measured at three sites. These measurements were taken using a flexible yet

inelastic tape measure. The circumference sites and skinfold-thickness measurement and procedures (Table 1), suggested by Lohman et al., (1988), were used. The skinfold and circumference measurements were recorded to the nearest millimeter. Corrected muscle girth was calculated:  $\text{circumference (cm)} - (3.14 * \text{skinfold (cm)})$ . Upon completion of the assessment and questionnaire, each subject was read a script (APPENDIX E) of procedures that the researcher followed to collect basal metabolic rate data.

Table 1

## Anthropometric measurement sites

Site	Skinfold-thickness measurement	Circumference measurement
Upper arm	Measured in the midline posteriorly over the triceps muscle at a point midway between the lateral projection of the acromion process of the scapula and the inferior margin of the olecranon process of the ulna	Measured midway between the lateral projection of the acromion process of the scapula and the inferior margin of the olecranon process of the ulna
Thigh	Measured at the midline of the anterior aspect of the thigh, midway between the inguinal crease and the proximal border of the patella	Measured midway between the midpoint of the inguinal crease and the proximal border of the patella
Calf	Measured on the medial aspect of the calf at the same level as the calf circumference	Measured at the maximal circumference

---

Lohman et al., (1988)

First, the subject was given a 20 minute resting period on an exam table in the lab, which included the reading of the script, and any questions the subject may have had. Subjects were in the supine position, it was important that the participant did not fall asleep.

Once the 20 minute rest period was completed, the researcher then began the process of assessing basal metabolic rate. The researcher instructed the participant to lie down on his back, placing his head in canopy. Each subject was given approximately 5 minutes to get

accustomed to the surroundings before the assessment began. The participant was asked to breathe as they would normally and try to remain calm. The subject maintained this position for approximately 15-20 minutes or until steady state has been obtained. Horner et al (2001), and Isbell et al (1991), suggested that steady state can be obtained with 10-minutes of data collection and have no more than 10% coefficient of variance. Therefore, the first 5 minutes and the last 5 minutes of assessment were discarded, and the remaining middle 10 minutes of data were used. The subject's BMR was measured using breath-by-breath indirect calorimetry. Respiratory exchange ratio was calculated by dividing  $VCO_2$  by  $VO_2$ .

BMR was calculated from breath-by-breath data using the Breeze 6.4.1 service software using an average of 10 minutes of stable measurements. The first and last 5 minutes were excluded. The results from indirect calorimetry were converted into BMR (kcal/min).  $VO_2$  (ml/min),  $VCO_2$  (ml/min) and RER ( $RER = VCO_2/VO_2$ ) were then converted into kilocalories (kcal/min) using the Weir Equation (Weir, 1949):

$$Kcal = [(1.1 RER) + 3.9] VO_2 (L/min)$$

The kcal/min were then multiplied by 1440 which is how many minutes are in a day, to obtain a basal metabolic rate measurement per day. After completion of the BMR assessment, the participant could leave. All the above methods and procedures can be found in APPENDIX G and APPENDIX H.

### **Statistical Analysis**

The independent variable in this study was skeletal muscle mass; the dependent variable was basal metabolic rate. SPSS software for Windows (Version 18) was used for statistical analysis. A scatter plot diagram was used to investigate the positive correlation between basal metabolic rate and skeletal muscle mass. The value of  $r$  indicated the strength

of correlation and was also a measure of effect size. Values of 0 to 0.2 were considered weak, 0.3 to 0.6 were considered moderate, and 0.7 to 1.0 were considered strong. A  $p < .05$  was considered to be significant. All graphs were made using Microsoft Excel 2010.

## Chapter 4

### Results

The purpose of this study was to determine the strength of the correlation between skeletal muscle mass and basal metabolic rate. Skeletal muscle mass was calculated the formula  $SMM (kg) = Ht (0.00744 CAG^2 + 0.00088 CTG^2 + 0.00441 CCG^2) + 2.4 \text{ sex} - 0.048 \text{ age} + \text{race} + 7.8$  (Lee et al., 2000). In this equation, sex = 1 for male and 0 for female (although no females are in the current study), race = -2.0 for Asian, 1.1 for African American, and 0 for white or Hispanic (Lee et al, 2000). CAG, CTG, and CCG represent skinfold-corrected upperarm, thigh, and calf circumferences respectively. Some participants volunteered only one day, and some volunteered both days. Volunteers that participated only one day, due to complications with equipment, were labeled the Half Participation group. Volunteers that participated both days were labeled the Full Participation Group. An average of the two days was taken to develop one data point for each volunteer. To show high reliability and validity, and low variability, a comparison between the two days will be shown in a few of the graphs before showing all subjects as one group. In this section graphs will be shown with and without subject 11 to determine if subject 11 is an outlier. Looking at the data in Table 2A, subject 11 had a SMM of 48.4kg and a BMR of 2982 kcal/day. These were the highest SMM and BMR of any subject in the study.

### Anthropometrics

Anthropometric measurements such as physical characteristics and body-composition measurements are illustrated in Table 2. The mean age of all subjects was 21 years old ( $SD = 0.7$ ). The mean body weight was 80.3 kg ( $SD = 11.4$ ) and the mean height was 174.6 cm

( $SD = 0.1$ ). Fifteen white males, one Hispanic male, and one African American male participated in the study.

Table 2

Subjects' physical characteristics and body-composition at baseline<sup>1</sup>

	All Subjects	Level of Participation	
	Men ( $n = 17$ )	Full ( $n = 9$ )	Half ( $n = 8$ )
Age (yr)	$21 \pm 0.7$	$21 \pm 0.9$	$21.3 \pm .1$
Body weight (kg)	$80.3 \pm 11.4$	$78.8 \pm 10.6$	$83.6 \pm 13.9$
Height (cm)	$174.6 \pm 0.1$	$174.9 \pm 0.1$	$173.8 \pm .08$
BMI ( $\text{kg}/\text{m}^2$ )	$26.2 \pm 2.5$	$25.7 \pm 2.5$	$27.5 \pm 2.2$
Race			
White	15	8	7
Hispanic	1	0	1
African American	1	1	0
% Body Fat	$12.4 \pm 3.3$	$11.3 \pm 2.9$	$15.2 \pm 2.5$
Circumference (cm)			
Midupper arm	$34.7 \pm 3.6$	$34.2 \pm 3.7$	$35.8 \pm 3.1$
Midthigh	$56.4 \pm 5.3$	$55.5 \pm 5.4$	$58.4 \pm 4.7$
Midcalf	$37.6 \pm 3.1$	$37.1 \pm 3.0$	$38.8 \pm 3.1$
Skinfold thickness (mm)			
Triceps	$14.6 \pm 5.1$	$13.6 \pm 4.1$	$16.8 \pm 6.6$
Midthigh	$14.9 \pm 5.7$	$13.3 \pm 3.9$	$18.7 \pm 7.4$
Midcalf	$10.0 \pm 2.6$	$9.0 \pm 1.7$	$12.0 \pm 3.2$
Corrected circumference (cm)			
CAG	$30.2 \pm 3.72$	$29.9 \pm 3.5$	$30.5 \pm 4.3$
CTG	$51.7 \pm 4.8$	$51.4 \pm 5.1$	$52.5 \pm 4.4$
CCG	$34.5 \pm 2.9$	$34.3 \pm 2.9$	$35 \pm 3.0$
Skeletal muscle mass (kg)	$34.9 \pm 6.1$	$34.5 \pm 5.9$	$35.3 \pm 6.8$
Basal Metabolic Rate (kcal/day) Weir	$2130.65 \pm 444.2$	$2044.4 \pm 365.3$	$2224.9 \pm 536.4$

<sup>1</sup>CAG, corrected arm girth; CTG, corrected thigh girth; CCG, corrected calf girth.

<sup>2</sup> $\bar{x} \pm SD$ .



Table 2A shows skeletal muscle mass and basal metabolic rate values for each participant.

Table 2A

<i>Skeletal Muscle Mass and Basal Metabolic Rate data</i>	
SMM	BMR
31.5	1984
34.1	2303
30.2	1828
42.8	2766
36.3	1847
45.1	2337
29.1	1908
28.8	1617
28.8	1528
48.4	2982
32.9	2356
32.7	1567
34.7	2154
27.7	1885
35.6	2672
42.3	2655

### Physiological Measurements

Physiological measurements that were obtained when assessing BMR are illustrated in Table 3. The average RER value was 0.8 ( $SD = 0.05$ ) for all subjects ( $n = 17$ ). A resting RER should range from 0.7-0.8 (Wilmore, Costill & Kenney, 2008). RER values of  $<0.7$  and  $>1.0$  were not be used. The average METS for all subjects was 3.8 ml/kg/min ( $SD = 0.05$ ). The average  $VO_2$  (ml/min) for all subjects ( $n = 17$ ) was 309.8 ml/min ( $SD = 57.3$ ). The average Basal Metabolic Rate for all subjects was 2130 kcal/day ( $SD = 444.2$ ).

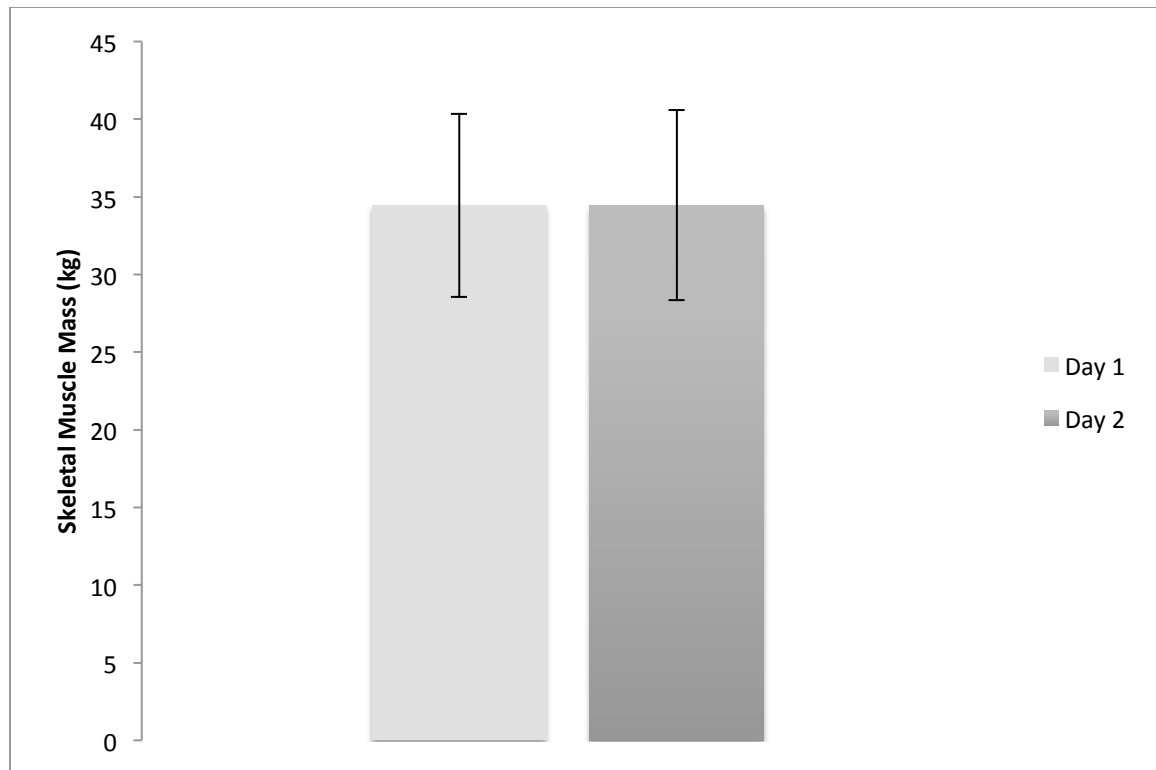
Table 3

Subjects' physiological characteristics at baseline.

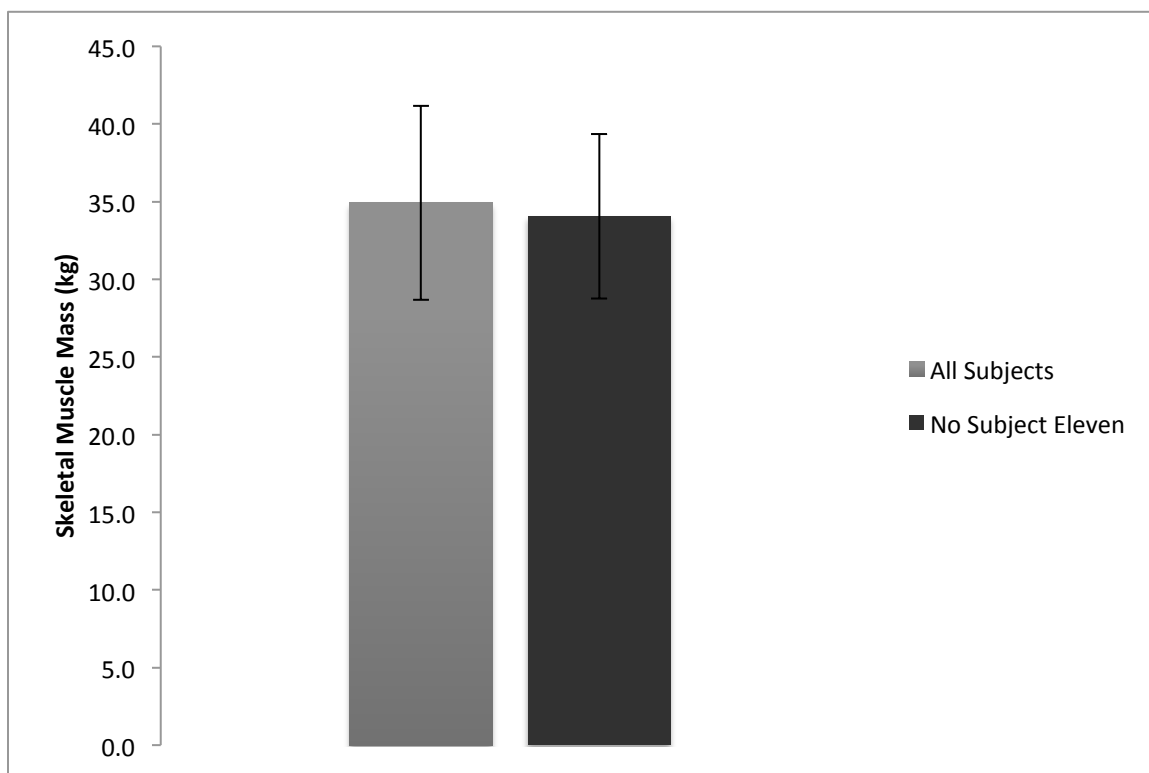
	All Subjects	Level of Participation	
	Men ( $n = 17$ )	Full ( $n = 9$ )	Half ( $n = 8$ )
RER Values	$0.8 \pm 0.05$	$0.8 \pm 0.05$	$0.8 \pm 0.06$
METS (ml/kg/min)	$3.8 \pm 0.4$	$3.7 \pm 0.4$	$3.8 \pm 0.5$
VO <sub>2</sub> (ml/min)	$309.8 \pm 57.3$	$302.8 \pm 50.4$	$325.0 \pm 71.9$
VCO <sub>2</sub> (ml/min)	$253.4 \pm 50.9$	$246.8 \pm 43.6$	$268.0 \pm 65.5$
Basal Metabolic Rate (kcal/day)	$2130.65 \pm 444.2$	$2044.4 \pm 365.3$	$2224.9 \pm 536.4$

### Skeletal Muscle Mass Assessment

The skeletal muscle mass measurements were reliable. There was no significant difference between skeletal muscle mass assessment for the two days for the Full Participation Group ( $n = 9$ ). The mean skeletal muscle mass on Day One was 34.45 kg ( $SD = 5.89$ ), whereas the Day Two mean skeletal muscle mass (kg) was 34.47 kg ( $SD = 5.90$ ) as shown in Figure 1. There was a strong positive correlation between the two days ( $r = 1.00$ ,  $n = 9$ ,  $p = 0.732$ ). There was no significant difference between SMM of all subjects versus all subjects except subject 11. . The mean SMM (kg) for all subjects, which included full and half participation groups, was 34.9 kg ( $SD = 6.25$ ) when subject 11 was included. The mean SMM (kg) was 34.1 kg ( $SD = 5.3$ ) when subject 11 was not included. There was no significant difference between days for all subjects versus all subjects except subject 11 ( $p = 0.670$ ) as shown in Figure 1A. Both figures show high reliability and low variability.

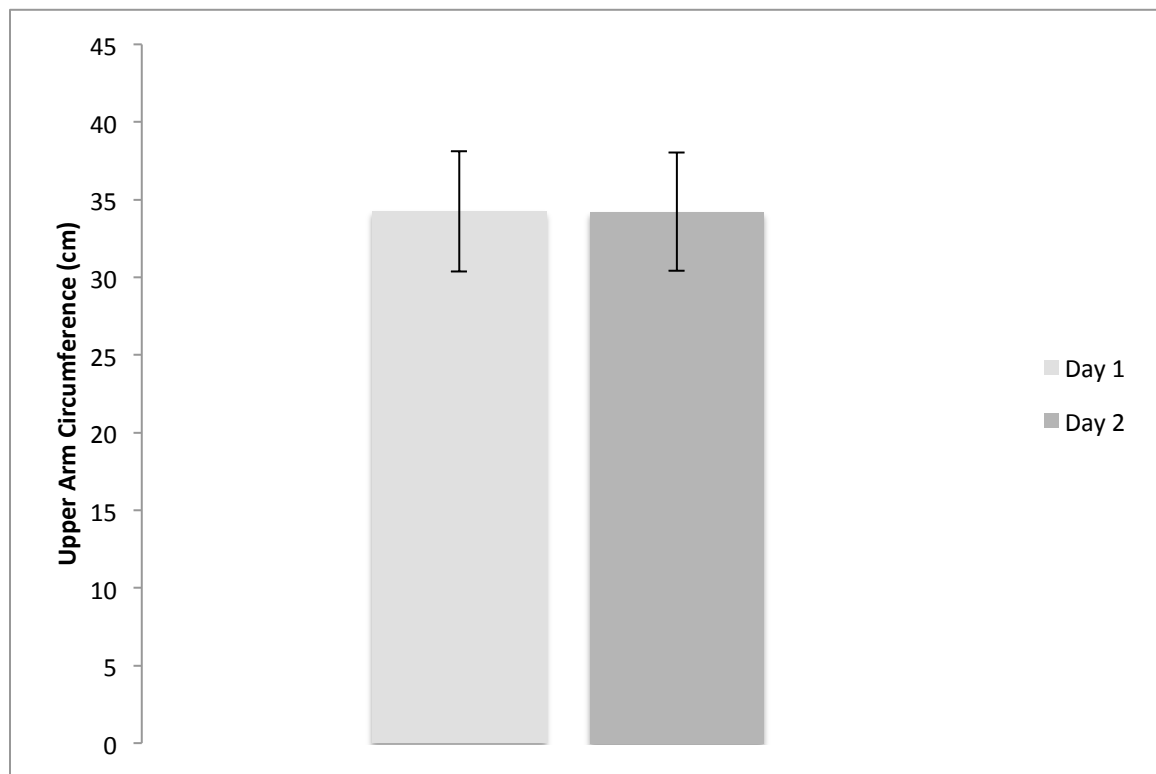


*Figure 1.* Graph compares Day 1 and Day 2 skeletal muscle mass measurements for the Full Participation group ( $n = 9$ ) to show low variability and high reliability. There is no significant difference ( $p = 0.732$ ) between Day 1 and Day 2 skeletal muscle mass measurements. The mean SMM on Day One was 34.45 kg ( $SD = 5.89$  kg). The mean SMM on Day Two was 34.47 kg ( $SD = 5.90$  kg).



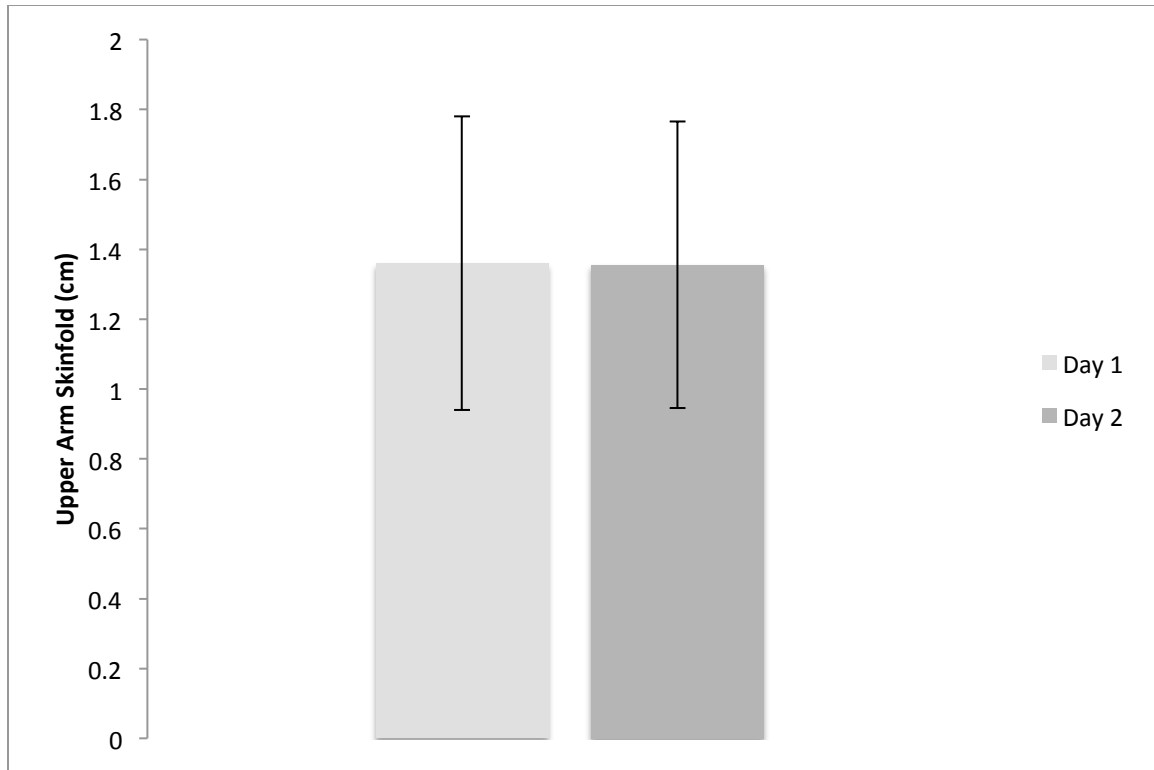
*Figure 1A.* Graph compares skeletal muscle mass measurements. This graph also shows all subjects as well as measurements with no subject 11. The mean SMM (kg) for all subjects ( $n = 17$ ) was 34.9 kg ( $SD = 6.25$ ), whereas the mean SMM (kg) is 34.1 kg ( $SD = 5.3$ ) when subject 11 is removed. There is no significant difference ( $p = 0.670$ ) all subjects and when subject number 11 is removed.

The circumference measurements were reliable. There was no significant difference between the circumference measurements for the two days. The mean upper arm circumference measurement on Day One was 34.25 cm ( $SD = 3.88$ ), whereas the mean measurement on Day Two was 34.22 cm ( $SD = 3.80$ ) as shown in Figure 2. There was a strong positive correlation between the two days ( $r = 0.99$ ,  $n = 9$ ,  $p = 0.714$ ).



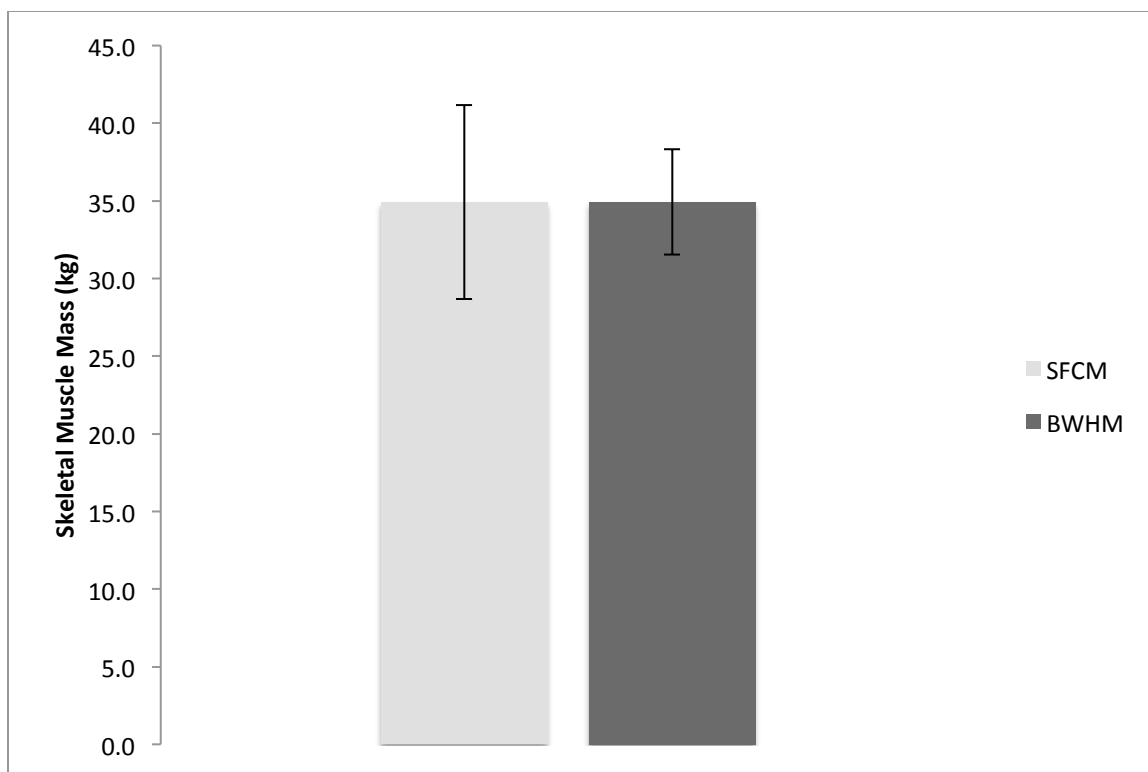
*Figure 2.* Graph comparing Day 1 and Day 2 upper arm circumference measurements(cm). There is no significant difference ( $p = 0.714$ ) between Day 1 and Day 2 upper arm circumference measurements ( $n = 9$ ). The mean upper arm circumference measurement on Day One was 34.25cm ( $SD = 3.88$ ), whereas the Day Two mean was 34.22cm ( $SD = 3.80$ ).

The skinfold measurements were reliable. There was no significant difference between skinfold measurements for the two days . The mean upper arm skinfold measurement on Day One was 1.36cm ( $SD = 0.422$ ), whereas the Day Two mean was 1.35cm ( $SD = 0.416$ ) as shown in Figure 2A. There was a strong positive correlation between the two days ( $r = 0.97$ ,  $n = 9$ ,  $p = 0.884$ ).



*Figure 2A.* Graph comparing Day 1 and Day 2 upper arm skinfold measurements(cm). There is no significant difference ( $p=.884$ ) between Day 1 and Day 2 upper arm circumference measurements ( $n = 9$ ). The mean upper arm skinfold measurement on Day One was 1.36cm ( $SD = 0.422$ ), whereas the Day Two mean was 1.35cm ( $SD = 0.416$ ).

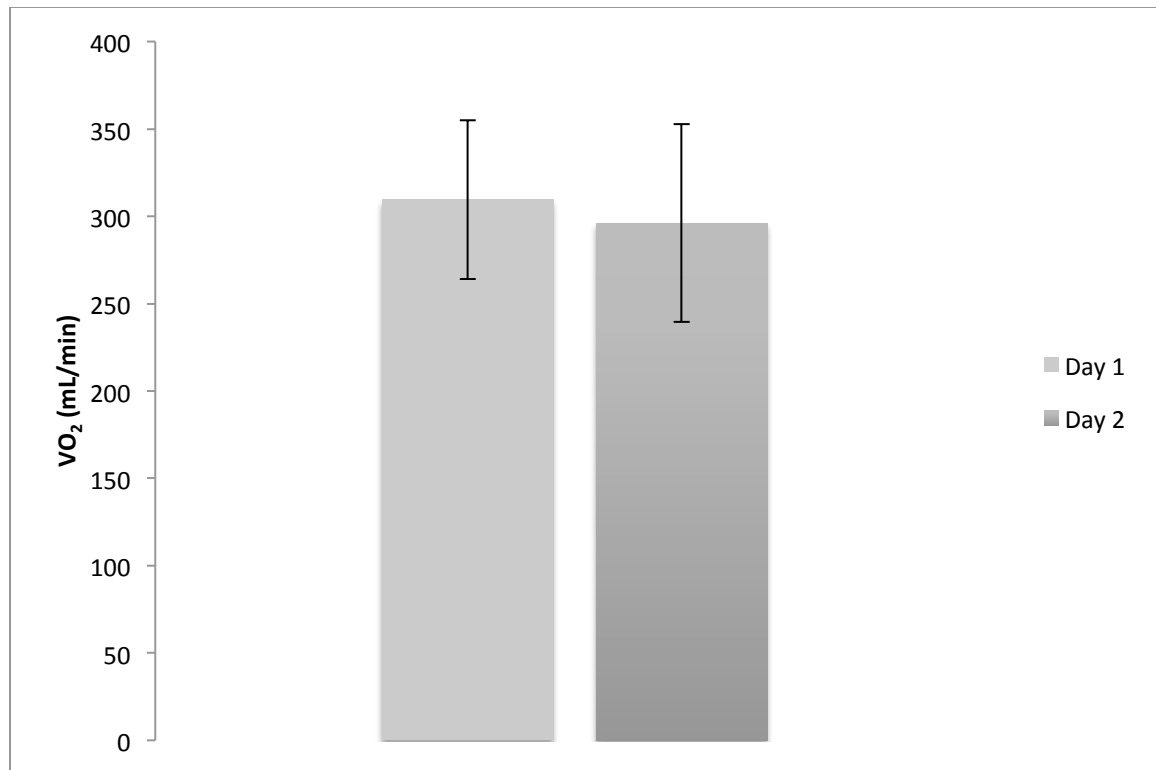
The skinfold-circumference (SFCM) skeletal muscle mass equation Lee et al. (2000),  $SMM (kg) = Ht (0.00744 CAG^2 + 0.00088 CTG^2 + 0.00441 CCG^2) + 2.4 \text{ sex} - 0.048 \text{ age} + \text{race} + 7.8$ , was used in the current study. The SMM from the previously mention equation was compared to a body-weight and height equation also by Lee et al. (2000),  $SMM = 0.244 BW + 7.8 Ht + 6.6 \text{ sex} - 0.098 \text{ age} + \text{race} - 3.3$ . The results are shown in Figure 3. There was no significant difference between the two formulas ( $p = 0.988$ ). The mean SFCM muscle mass was 34.9kg ( $SD = 6.25$ ), the mean BWHM muscle mass was 34.9kg ( $SD = 3.39$ ). There was a strong positive correlation ( $r = 0.87$ ,  $n = 17$ ,  $p = 0.988$ ).



*Figure 3.* Graph comparing SFCM and BWHM skeletal muscle mass measurements. There is no significant difference ( $p = 0.988$ ) between the two skeletal muscle mass formulas. The mean SFCM muscle mass was 34.9kg ( $SD = 6.25$ ), the mean BWHM muscle mass was 34.9kg ( $SD = 3.39$ ). There was a strong positive correlation ( $r = 0.87$ ,  $n = 17$ ,  $p = 0.988$ ).

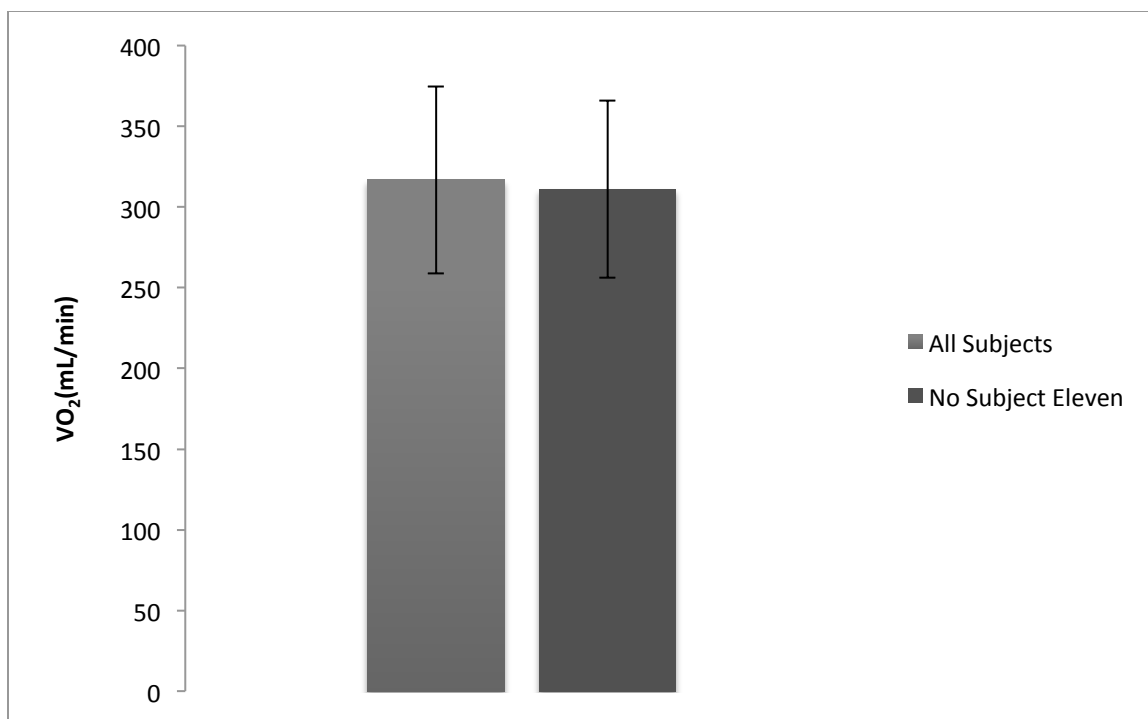
### Oxygen Consumption

There was no significant difference between the two days of  $VO_2$  measurements. The  $VO_2$  measurements provide raw data points needed to calculate BMR. The mean  $VO_2$  on Day One was 309.4 ml/min ( $SD = 45.5$ ), whereas the Day Two mean  $VO_2$  was 296.1 ml/min ( $SD=56.7$ ) as shown in Figure 4. There was a strong positive correlation between the two days ( $r = 0.866$ ,  $n = 9$ ,  $p = 0.199$ ). There was no significant difference between the two days for all subjects versus all subjects except subject 11 as shown in Figure 4A. The mean  $VO_2$  for all subjects was 316.7 ml/min ( $SD=58.0$ ), whereas the mean  $VO_2$  for all subjects except subject 11 was 311.1 ml/min ( $SD=54.9$ ). There was no significant difference between all subjects and all subjects except subject 11 ( $p = 0.77$ ).



*Figure 4.* Graph comparing Day 1 and Day 2 VO<sub>2</sub> measurements. There was a strong positive correlation between the two days ( $r = 0.866$ ,  $n = 9$ ,  $p = 0.199$ ). The mean VO<sub>2</sub> on Day One was 309.4 ml/min ( $SD = 45.5$ ), whereas the Day Two mean VO<sub>2</sub> was 296.1 ml/min ( $SD = 56.7$ ).





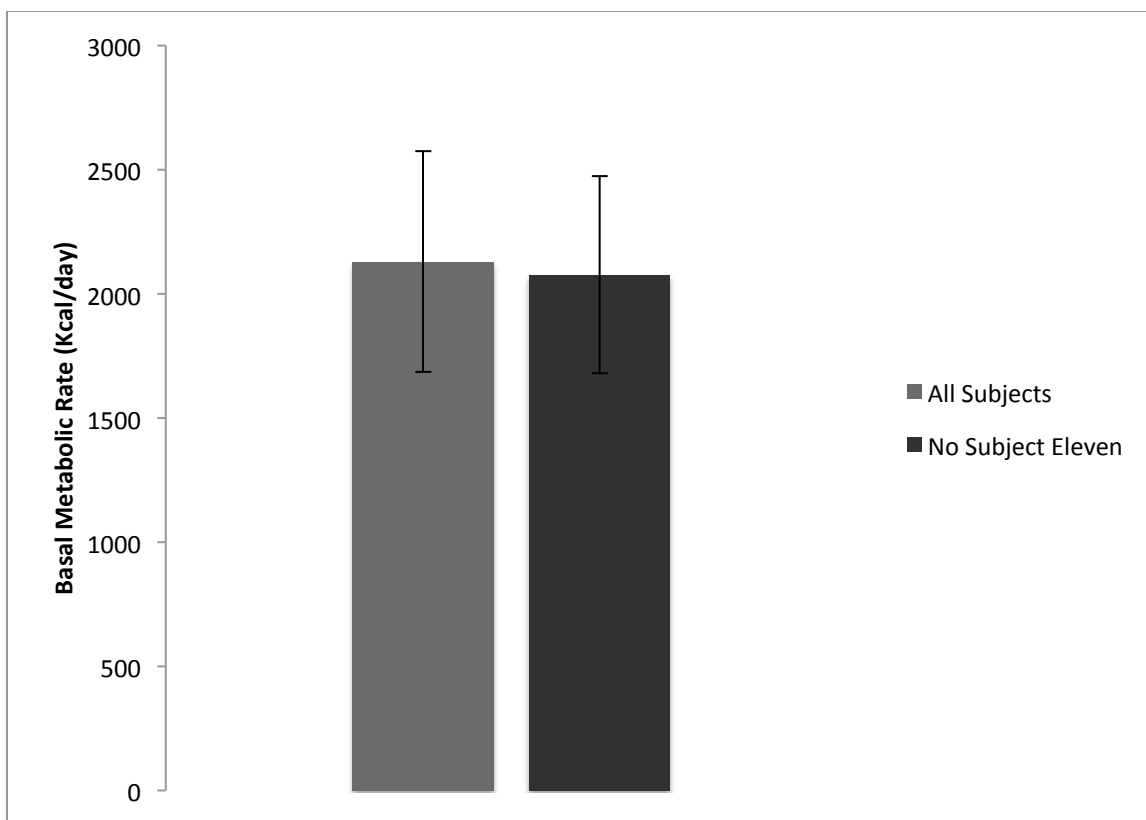
*Figure 4A.* Graph comparing measurements between all subjects and when subject 11 was removed. There is no significant difference ( $p = 0.77$ ) between all subjects and no subject 11. The mean  $VO_2$  for all subjects was 316.7 ml/min ( $SD = 58.0$ ), whereas the mean  $VO_2$  when there was no subject 11 was 311.1 ml/min ( $SD = 54.9$ ).

### Basal Metabolic Rate Assessment

There was no significant difference between the two days of basal metabolic rate (BMR) measurements. The mean BMR on Day One was 2107.55 kcal/day ( $SD=318.00$ ), whereas the Day Two mean BMR was 1985.66 kcal/day ( $SD=413.39$ ) as shown in Figure 5. There was a strong positive correlation between the two days ( $r = 0.884$ ,  $n = 9$ ,  $p = 0.103$ ). There was no significant difference between the two days for all subjects versus all subjects except subject 11. The mean BMR for all subjects was 2103 kcal/day ( $SD = 444$ ), whereas the mean BMR for all subjects except subject 11 was 2077 kcal/day ( $SD = 398$ ) as shown in Figure 5A. There was no significant difference between all subjects and all subjects except subject 11 ( $p = 0.719$ ).



*Figure 5.* Graph comparing Day 1 and Day 2 BMR measurements. There was no significant difference ( $p = 0.103$ ) between Day 1 and Day 2 BMR measurements. The mean BMR on Day One was 2107.55 kcal/day ( $SD = 318.00$ ), whereas the Day Two mean BMR was 1985.66 kcal/day ( $SD = 413.39$ ).



*Figure 5A.* Graph comparing measurements of basal metabolic rate. This graph shows all subjects as well as measurements with not subject 11. There is no significant difference ( $p=0.719$ ) between all subjects and when subject number 11 is removed. The mean BMR for all subjects was 2103 kcal/day ( $SD = 444$ ), whereas the mean BMR when there was no subject 11 was 2077 kcal/day ( $SD = 398$ ).

### Representative Participant Showing Low Variability

The previous graphs show low variability and high reliability among measurements between the subjects in this study. The following graphs show data from representative participants, showing high reliability and low variability.

The mean RER for the twenty minute assessment for a volunteer shown was 0.80 ( $SD = 0.02$ ) Figure 6. The mean RER for the middle ten minutes of assessment was 0.80 ( $SD = 0.01$ ) as shown in Figure 6A.

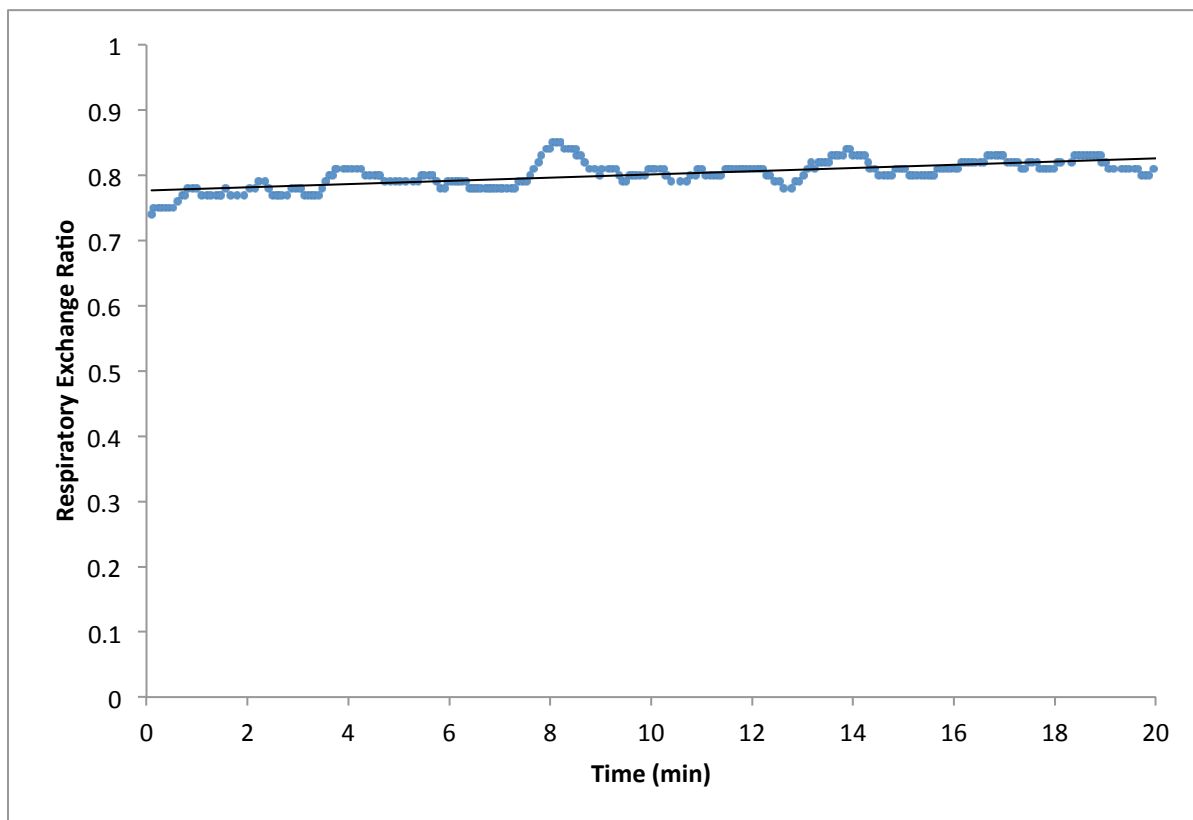


Figure 6. Respiratory exchange ratio over full twenty minute assessment from one representative sample. Mean RER 0.80 ( $SD = 0.02$ )

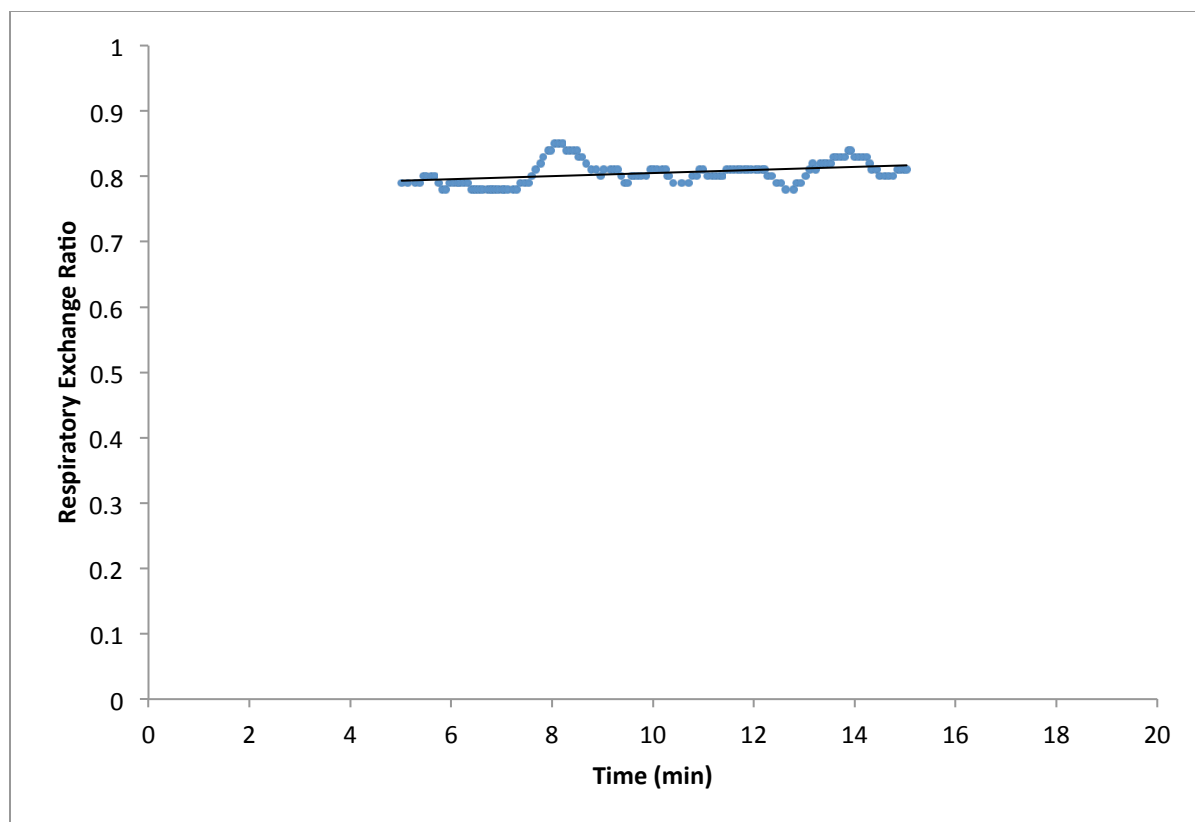
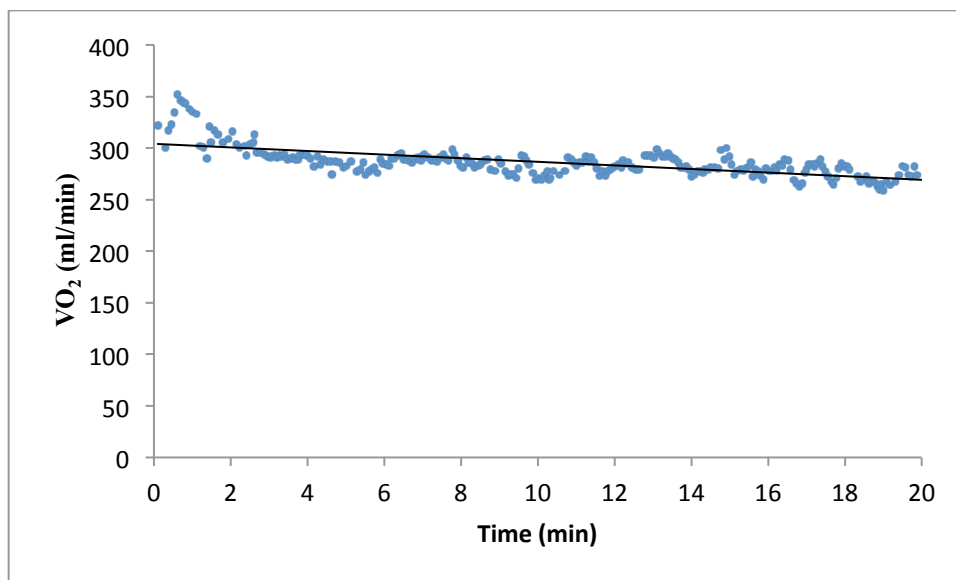


Figure 6A. Respiratory exchange ratio over middle ten minutes from one representative sample. Mean RER 0.80 ( $SD = 0.01$ )

Illustrated in Figures 7 and 7A are examples of BMR assessment for one representative sample. Figure 7 represents the full twenty minute  $\text{VO}_2$  assessment of one representative sample. The average  $\text{VO}_2$  is 286.6 ml/min. The minimum  $\text{VO}_2$  was 259 ml/min and the maximum  $\text{VO}_2$  was 352 ml/min.



*Figure 7.* Overall  $\text{VO}_2$  assessment for one representative sample. The mean  $\text{VO}_2$  was 286.6 ml/min, the minimum  $\text{VO}_2$  was 259 ml/min, and the maximum  $\text{VO}_2$  was 352 ml/min.

Figure 7A represents the middle 10 minutes of a basal metabolic rate assessment for one representative sample. The average  $\text{VO}_2$  during the middle 10 minutes of the assessment was 274.9 ml/min. The minimum  $\text{VO}_2$  was 269 ml/min and the maximum  $\text{VO}_2$  was 300 ml/min.

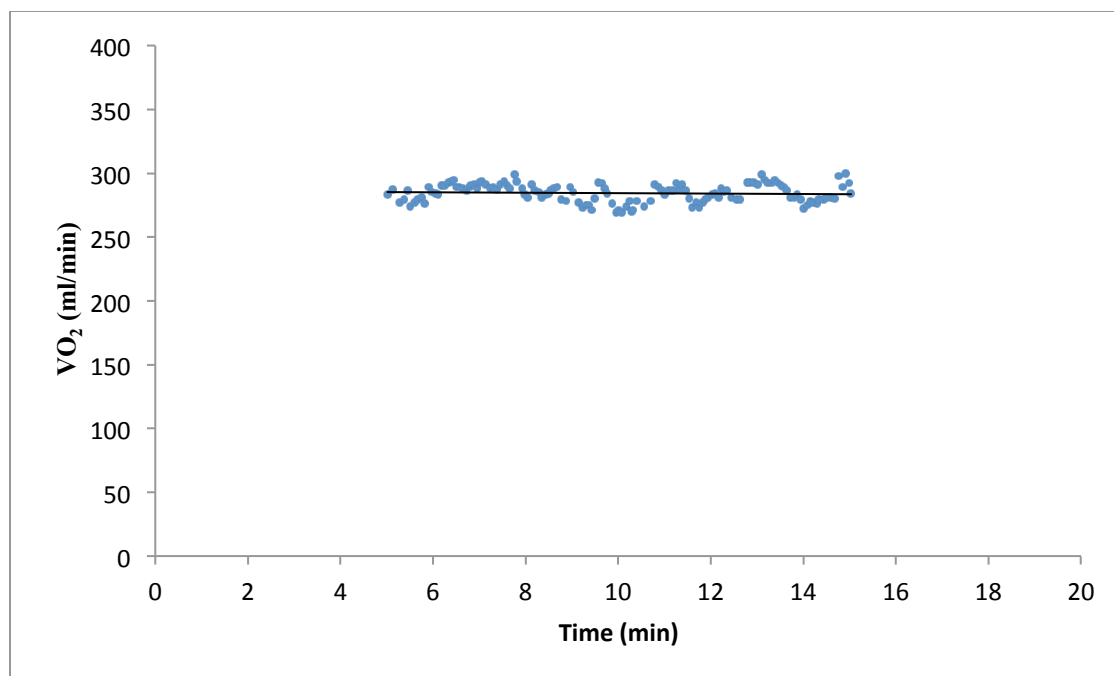


Figure 7A. Middle ten minutes of the VO<sub>2</sub> assessment for one representative sample. The mean VO<sub>2</sub> was 274.9 ml/min, the minimum VO<sub>2</sub> 269 ml/min, and the maximum VO<sub>2</sub> was 300 ml/min.

The overall average RER for all subjects was 0.81 ( $SD = 0.05$ ) where the minimum was 0.72, and the maximum was 0.95 as shown in Figure 8 where RER was plotted against SMM. The highest SMM did not have the highest RER, however, all participant values are within the range between  $> 0.7 - < 1.0$ .

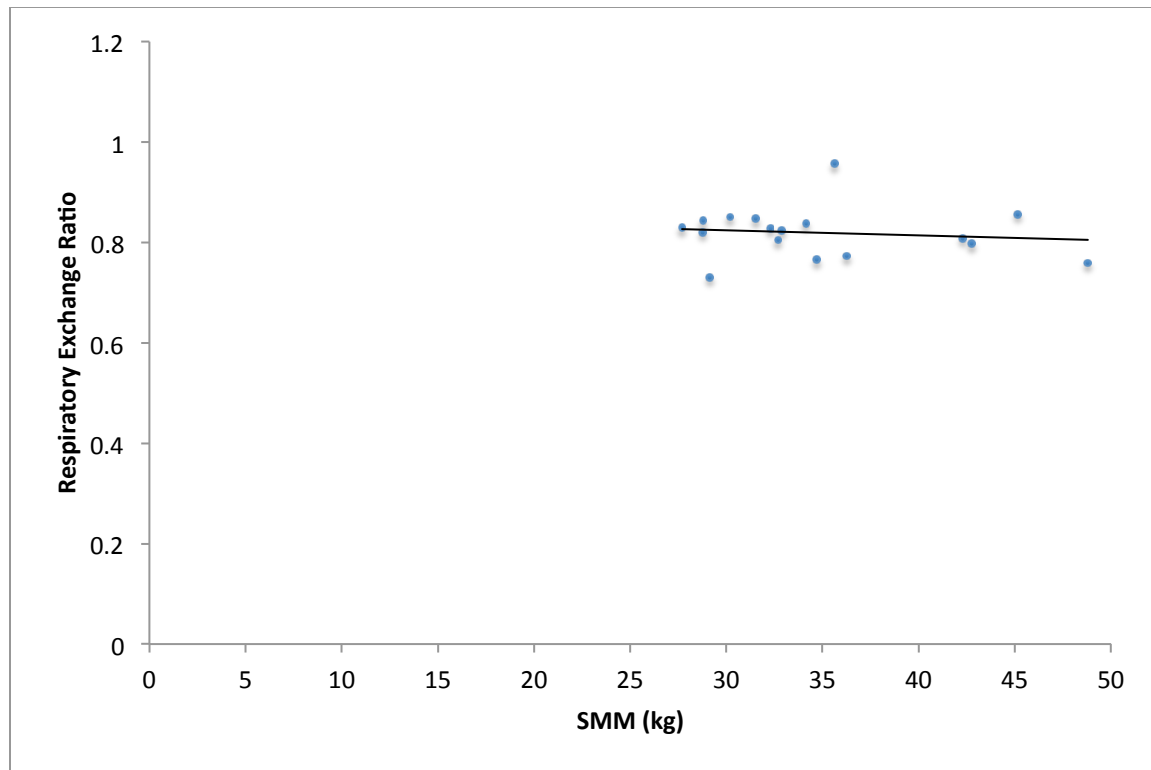


Figure 8. RER plotted against SMM. Average RER was 0.81 ( $SD = 0.05$ ). All RER values were within the range between  $>0.7 - < 1.0$ .

### Skeletal Muscle Mass, Basal Metabolic Rate, and Oxygen Consumption

Basal metabolic rate was plotted against the skeletal muscle mass values. The graph for BMR versus skeletal muscle mass (SMM) shown in Figure 9 shows a positive linear relationship.  $R^2 = 0.65$ , meaning the differences in SMM accounted for 65% of the variability in BMR, indicating a moderate relationship between SMM and BMR. The relative difference between the subject with the lowest BMR and the subject with the highest BMR was 95%. The relative difference between the subject with the lowest SMM and the highest SMM was 75%.



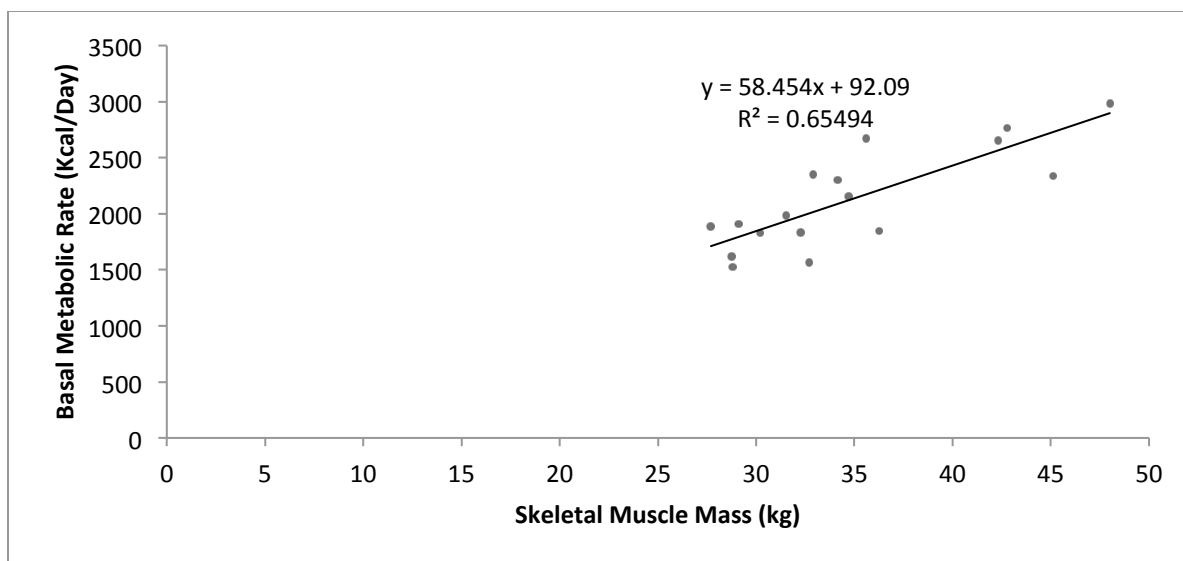


Figure 9. BMR versus SMM fall all subjects. The regression line predict BMR from SMM,  $Y = 58.454x + 92.09$ ,  $R^2 = 0.65$ .

Basal metabolic rate was also plotted against skeletal muscle mass values without subject 11. The graph for BMR verses SMM (Figure 9A) shows a positive linear relationship.  $R^2 = 0.54$ , meaning the differences in SMM accounted for 65% of the variability in BMR, indicating there was a moderate relationship between SMM and BMR.

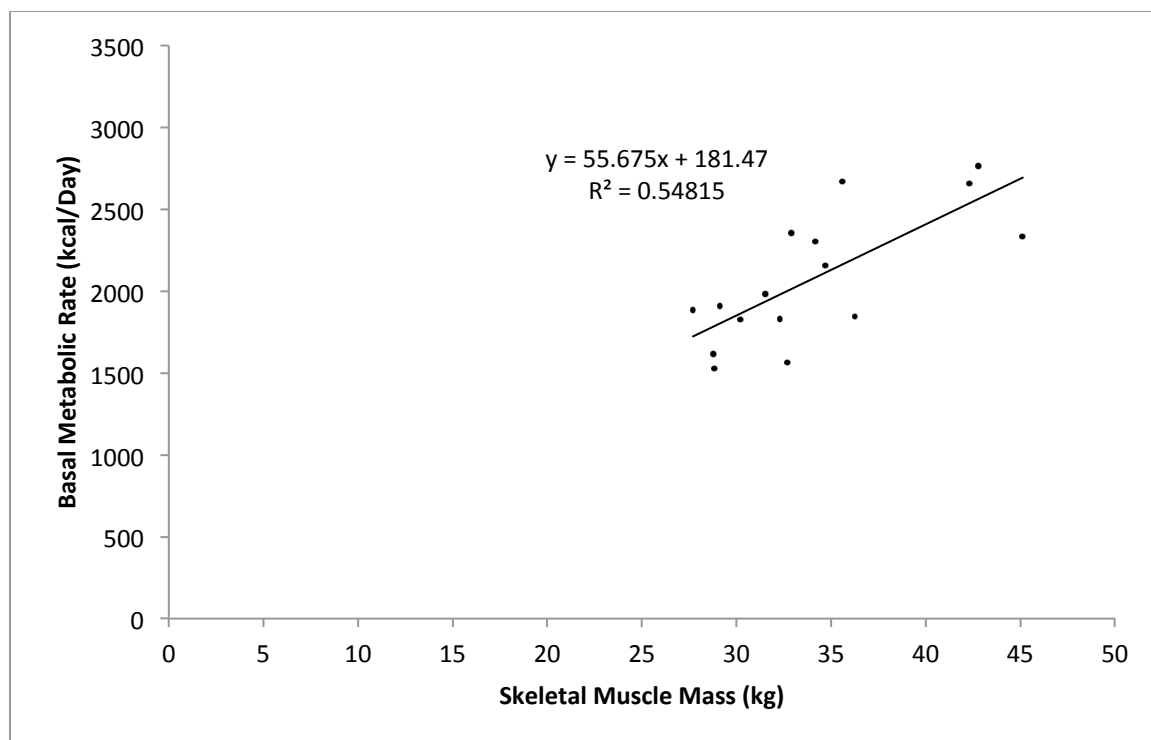


Figure 9A. BMR versus SMM without subject 11. The regression line predicts BMR from SMM,  $Y = 55.675x + 161.47$ ,  $R^2 = 0.54$ .

The mean body mass was 81.10 kg ( $SD = 12.56$ ). There was a strong positive correlation between BM and BMR ( $r = 0.82$ ,  $n = 17$ ) as shown in Figure 10.

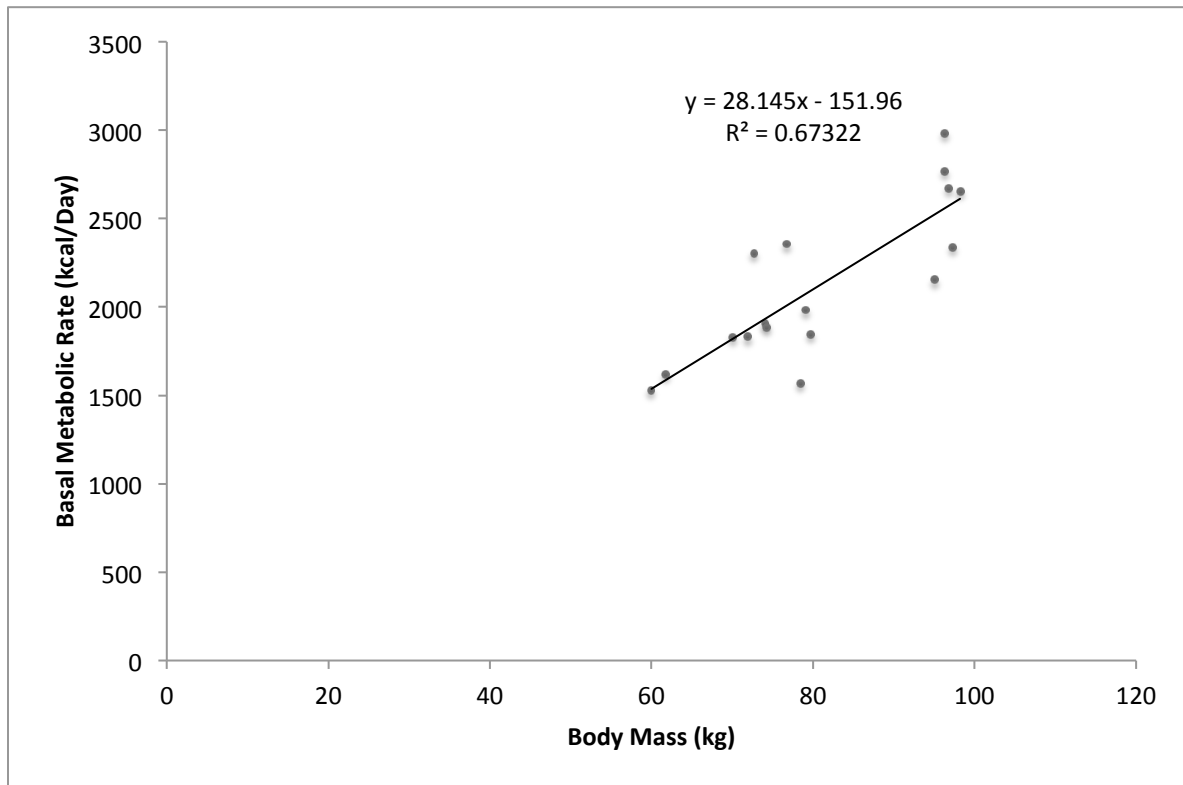
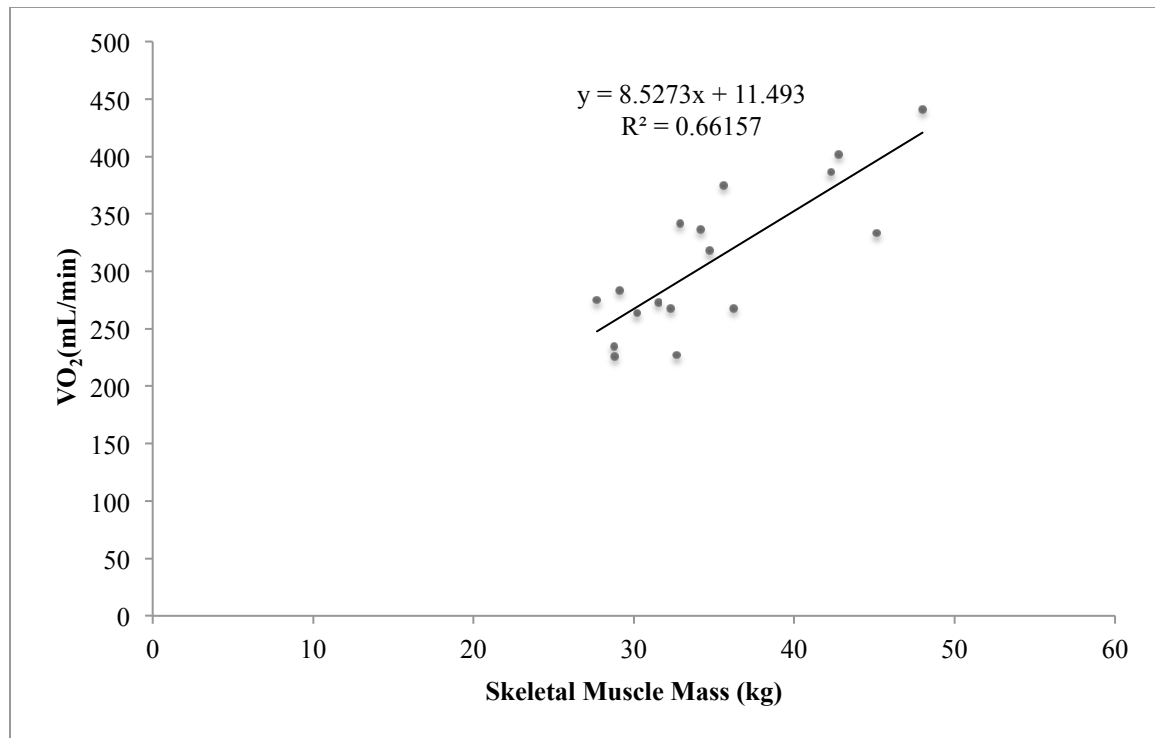


Figure 10. Body Mass (kg) and BMR. The regression line predicts BMR from BM,  $Y = 28.145x + 151.96$ ,  $R^2 = 0.6732$ .

$VO_2$  was plotted against the skeletal muscle mass values as shown in Figure 11. The graph for  $VO_2$  versus SMM shows a positive linear relationship.  $R^2 = 0.66$ , meaning the differences in SMM accounted for 66% of the variability in  $VO_2$ , indicating a moderate relationship between SMM and  $VO_2$ .



*Figure 11.*  $VO_2$  versus SMM. The regression line predicts  $VO_2$  from SMM,  $Y = 8.52x + 11.49$ ,  $R^2 = 0.66$ .

The overall average for RER in all subjects was 0.81 ( $SD = 0.05$ ) where the minimum was 0.72, and the maximum was 0.95 as shown in Figure 12 where RER was plotted against BMR. As BMR increases, RER stays within the suggested range of RER at rest.

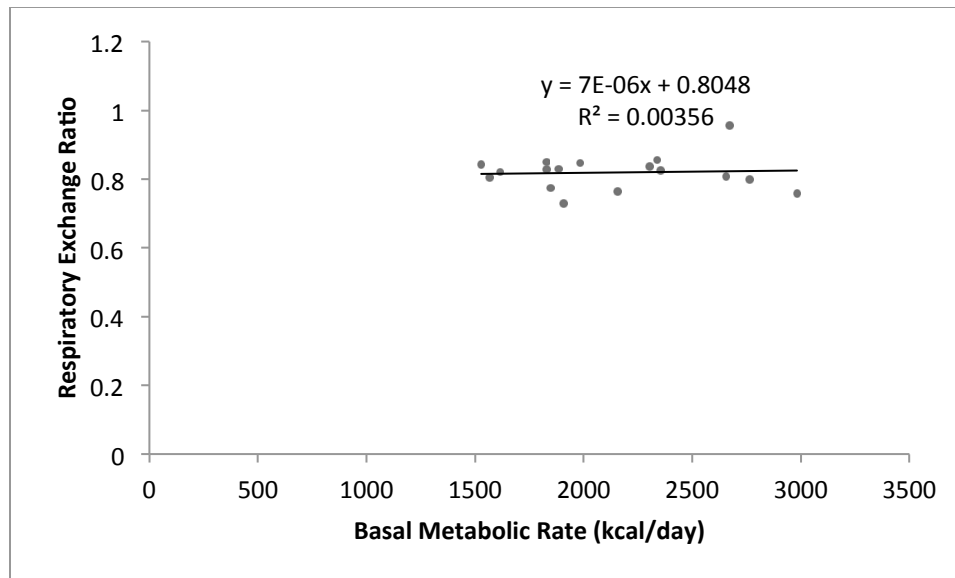


Figure 12. RER plotted against BMR. The average RER was 0.81 ( $SD = 0.05$ ).

The purpose of this study was to determine the strength of the correlation between skeletal muscle mass and basal metabolic rate. It was determined that there was no significant difference between measures for all subjects versus measures for all subjects except subject 11 for both skeletal muscle mass ( $p = 0.67$ ) and basal metabolic rate ( $p = 0.719$ ). Therefore, all subjects were used. It was determined that there was no significant difference between Day One and Day Two for both skeletal muscle mass measurements ( $p = 0.732$ ) and basal metabolic rate ( $p = 0.103$ ). The low variability and high reliability of all measurements allowed the researcher to include the Half Participation group. BMR was plotted against SMM which showed a positive linear relationship  $r^2 = 0.65$  and a high correlation  $r = 0.80$ . Based on the methods used and the statistical analysis of the data collected, results of this study suggest that an SMM is strongly associated with BMR. There was a 95% difference in kcal/day between the subject with the lowest BMR and SMM and the subject with the highest BMR and SMM.

## Chapter 5

### Discussion, Conclusion, and Recommendations.

#### Discussion

The purpose of this study was to determine the strength of the correlation between skeletal muscle mass and basal metabolic rate. The hypothesis of this study was that basal metabolic rate would be strongly correlated with greater skeletal muscle mass. Also, the researcher compared the results to findings of Dolezal and Potteiger (1998). Dolezal and Potteiger (1998) found that a resistance trained (RT) group had the highest BMR when compared to an aerobically trained (AT) group and a group that preferred a combination of aerobic and resistance training (CT). The current study also compared anthropometric measurements to Lee et al. (2000) and Minghelli et al. (1998). In the following sections, the current study will be compared to results obtained in these other studies.

#### Anthropometric Measurements

As shown in Table 2, the current study collected anthropometric measurements from 17 non-obese college-age males. The average body weight (BW) was 80.3kg ( $SD = 11.4$ ) and the average skeletal muscle mass (SMM) was 34.9kg ( $SD = 6.1$ kg). In the research by Lee et al. (2000), 135 non-obese men had the same anthropometric measurements obtained. The average BW for subjects studied by Lee et al. (2000) was 79.0 kg ( $SD = 11.7$ ) and the average SMM was 32.6 kg ( $SD = 5.2$ kg) as shown in Table 4. The current study used the same formula to determine SMM as that used by Lee et al. (2000).

Table 4

Comparison of BW, BMI, and SMM between current study and research by Lee et al., (2000)		
	Current Study ( <i>n</i> =17)	Lee et al., (2000) ( <i>n</i> =135)
Body Weight (kg)	80.3 ± 11.4	79.0 ± 11.7
BMI (kg/m <sup>2</sup> )	26.2 ± 2.5	25.2 ± 3.1
SMM (kg)	34.9 ± 6.1	32.6 ± 5.2

### Basal Metabolic Rate

In a longitudinal study by Buscemi et al. (2005), a correlation between a relatively low BMR and body weight gain was observed in Caucasian Italians. The results of the study showed that a low BMR was indeed associated with weight gain in Caucasian Italians. Instead of using predictive equations, Buscemi et al. used body composition, which was measured by bioelectric impedance, fat mass percentage, and indirect calorimetry. Minghelli et al. (1990), measured BMR in Gambian men during the “hunger season” as well as European men that had similar body composition. The results of the current study were compared to Minghelli et al. (1990), as shown in Table 5. Although the Gambian men had a lower body weight and a lower BMR, the European men had lower body weight and a higher BMR when compared to the current study.

The current study used a metabolic cart and converted the VO<sub>2</sub> data obtained into basal metabolic rate (kcal/day) using the Weir equation as reported by Weir (1949). The participants in this study were 17 college age males from the United States. The BW of the U.S. males was higher than that of the other two groups as measured in Minghelli et al., (1990). Although there was a higher BW in the current study, it is interesting to see that European men had a higher BMR.

Table 5

Comparison of BW and BMR between current study to research by Minghelli et al., (1990)			
	Current Study	Minghelli et al., (1990)	
		Gambian	European
Body Weight (kg)	80.3 $\pm$ 11.4	60. $\pm$ 1.4	66.9 $\pm$ 1.9
BMR (kcal/day)	2130 .65 $\pm$ 444.2	2047 $\pm$ 46	2635 $\pm$ 74

### Basal Metabolic Rate, Skeletal Muscle Mass, and Fat-Free Mass

Walberg (1989) suggested that weight training can increase muscle. However, when compared to aerobic exercise, it was less likely to result in an increase in FFM and RMR and a decrease in body fat. Other studies have shown an elevation in BMR in resistance trained athletes whereas other studies showed a decrease in BMR in subjects that participated in a combination of aerobic and resistance exercise programs. It is important for an exercise program to show a successful reduction in body fat and an increase in fat free mass (Cunliffe & Stiegler, 2006).

As explained previously, according to Table 5,  $R^2 = 0.65$ . This means that the change in SMM accounted for 65% of the change in BMR, indicating a moderate relationship between change in SMM and BMR. The results of this study further support that an increase in SMM or FMM can result in an increase in BMR. The question is, although any type of training can be beneficial, which type of training is the most beneficial in terms of increasing BMR? This is further explained in the following section.

### Resistance Training, Aerobic Training, Combination Training

The participants were split up by training preference and categorized. This was determined by the answer on the questionnaire. There was an aerobic group, resistance



group, and a group that prefers both types of training. As shown in Table 6, the aerobic trained (AT) group ( $n = 3$ ) had a mean SMM of 31.3 kg ( $SD = 3.5$ ). The resistance-trained (RT) group ( $n = 10$ ) had a mean SMM of 36.6 kg ( $SD = 6.7$ ). The combination trained (CT) group ( $n = 4$ ), had a mean SMM of 33.4 kg ( $SD = 6.1$ ). The aerobic trained (AT) group ( $n = 3$ ) had a mean BMR 2007.6 kcal/day ( $SD=136.0$ ). The resistance-trained (RT) group ( $n = 10$ ) had a mean BMR of 2235.5 kcal/day ( $SD=488.3$ ). The combination trained (CT) group ( $n = 4$ ), had a mean BMR of 1960.7 kcal/day ( $SD=484.2$ ).

Table 6

BMR (kcal/day) of participants with fitness preference.		
Training Preference	SMM	BMR
AT	31.3 $\pm$ 3.5	2007.6 $\pm$ 136.0
CT	33.4 $\pm$ 6.1	1960.7 $\pm$ 484.2
RT	36.6 $\pm$ 6.7	2235.5 $\pm$ 488.3

The participant in each group with the highest SMM also has the highest BMR within that group as shown in Table 7.

Table 7.

Comparison of the highest SMM (kg) had the highest BMR (kcal/day) within each group.		
Training Preference	SMM	BMR
AT	34.7	2154
CT	42.3	2655
RT	48.8	2982

The participants with approximately the same SMM were compared in Table 8.

Table 8

Comparison of participants with approximately the same SMM (kg) within each group.		
Training Preference	SMM	BMR
AT	27.7	1885
CT	28.8	1617
RT	28.8	1528

Dolezal and Potteiger (1998), studied thirty physically active healthy men with a mean age of 20 years old. They were assigned to one of three ten week training program groups: endurance trained (ET), resistance trained (RT), and a group that was trained with a combination of resistance and endurance trained (CT). The BMR of participants was measured before and after the 10-week training program of their specific group. The results of this study found that the RT group had a pre and post BMR of 1818 kcal/day ( $SD = 231$  kcal/day) to 1920 kcal/day ( $SD = 227$  kcal/day) respectively. The ET group had a pre and post BMR of 1727 kcal/day ( $SD = 132$  kcal/day) to 1678 kcal/day ( $SD = 159$  kcal/day) respectively. The CT group had a pre and post BMR of 1780 kcal/day ( $SD = 230$  kcal/day) to 1867 kcal/day ( $SD = 234$  kcal/day) (Dolezal & Potteiger, 1998). The pre and post assessment of BMR was significantly increased in the RT and CT groups but not for the ET group (Dolezal & Potteiger, 1998).

Wadden et al. (1997), studied changes in appetite, body composition, resting energy expenditure, and mood of 128 obese women. Each participant was assigned one of four treatment conditions: diet alone, diet plus aerobic training, diet plus strength training, or diet and a combination of aerobic and resistance training. Similar to the current study, the diet plus strength training group had higher resting energy expenditure than the aerobically trained group.

Table 9 compares two subjects who had identical BW and different training preferences. The noticeable difference is that the predicted BMR and the BMR computed via the Weir equation. Subject 1(aerobically trained) has a higher BMR than Subject 2 (resistance trained). This could be a result of subject 1 having a higher RER value. When using the Weir equation, when RER is increased, BMR will increase also. Subject 2 has a

higher SMM. The difference between both subjects could be that these are their preference on how they exercise. This may not mean that they are currently training to their preference.

Table 9

Comparison of Subjects 1 and 2		
	Subject 1	Subject 2
Training Preference	Aerobic	Resistance
Weight (kg)	79.09	79.77
V <sub>O<sub>2</sub></sub> (mL/min)	307	387
SMM (kg)	31.5	36.3
RER Values	.84	.77
Basal Metabolic Rate (kcal/day) Weir	1984	1847

Overall, when subjects were split into group based on training preference, subjects that preferred resistance training had a higher SMM and also had a higher BMR as explained in Figure 9. In Table 10, the current study is compared to a study by Dolezal and Potteiger (1998). When compared to other studies, it is supported that RT will increase BMR, and AT will increase endurance, CT will provide an increase in BMR but not as much as RT. The current study shows that the highest average SMM also has the higher average BMR as seen in the RT group. However, contrary to Dolezal and Potteiger (1998), the CT group in the current study does not have a higher average BMR than the AT group. The CT group however, has a higher average SMM. More research needs to be done with a larger number of participants within these two groups. The CT group ( $n=4$ ) and the AT group ( $n=3$ ) did not provide sufficient support to Dolezal and Pottieger (1998) conclusions as each group in

their study had 10 participants. The main similarity between the studies is that the group with a higher SMM, RT group, also had a higher BMR. The three groups were compared. All three groups were significantly different ( $p=0.07$ ).

Table 10

Comparison of current study to a study by Dolezal & Pottieger (1998)

	Current Study			Dolezal & Pottieger (1998)					
				Pre-Test			Post-Test		
	RT	AT	CT	RT	AT	CT	RT	AT	CT
BM(kg)	83.03 + 12.7	82.79 ± 10.9	75.0 ± 16.3						
BF (%)	12.7 ± 4.0	14.1 ± 1.2	12.7 ± 1.3	15.4 ± 2.7	11.8 ± 2.9	12.2 ± 2.7	14.0 ± 2.7	9.5 ± 1.7	8.7 ± 1.7
BMR(kcal/day)	2235 ± 488.3	2007 ± 136.0	1960 ± 484.2	1818 ± 231	1727 ± 132	1780 ± 230	1920 ± 227	1678 ± 159	1867 ± 234
SMM(kg)	36.6 ± 6.7	31.1 ± 3.5	33.4 ± 6.1						

## Summary

The purpose of this study was to determine the strength of the correlation between skeletal muscle mass and basal metabolic rate. It was hypothesized that SMM and BMR would be strongly correlated. The participants were seventeen college-aged males. Statistical analysis revealed that there was a strong positive correlation between skeletal muscle mass and basal metabolic rate. BMR was plotted against SMM which showed a positive linear relationship  $r^2 = 0.65$  and a high correlation  $r = 0.80$ . Based on the methods used and the statistical analysis of the data collected, results of this study suggest that an increase in SMM is associated with BMR. There was a 95% difference in kcal/day between the subject with the lowest BMR and SMM and the highest BMR and SMM.

All subjects ( $n=17$ ) were then separated into three separate groups. The resistance trained (RT), aerobically trained (AT), and the combination trained (CT) groups were significantly different when compared amongst each other. Even though there was a significant difference between groups, the researchers' hypothesis is accepted with a strong correlation between basal metabolic rate and skeletal muscle mass. The results were similar to the findings in the study by Dolezal and Potteiger (1998) in which the RT group had the highest SMM and BMR. Based on the current data, resistance training is recommended to expend more kcals/day at rest.

### **Conclusion**

Based on the methods used and the statistical analysis of the data collected, results of this study provide evidence suggesting that an increase in SMM can also increase BMR. Results also support the conclusion that, although the CT group has a lower BMR than the AT group in this study, there is a stronger correlation between SMM and BMR within the CT group. The CT group also had the second highest mean SMM. Based on the results of this study, a resistance-based training workout is recommended for increasing SMM. The increase in SMM will result in an increase in BMR.

### **Recommendations**

Future research is recommended. Future researchers could increase the number of participants in the AT and CT groups. This would allow for a more accurate comparison to other studies such as Dolezal & Potteiger (1998). Although following the same SMM and BMR measurements is recommended, a training study where data are collected pre- and post-training is also recommended.

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Appendix A  
State University of New York College at Cortland

Kinesiology Department

Informed Consent

The study that you are being asked to participate in involves research. The purpose of this study is to determine the effect skeletal muscle mass has on basal metabolic rate. The subjects will be asked to meet twice. The first meeting will be to discuss the pre-test guidelines and allow the subject to ask the researcher any questions. The second meeting will be about an hour to an hour and a half long in which the Participants will be asked to complete measurements that will determine resting energy expenditure. Measurements such as body weight (kg), Height (cm), and circumference (cm) of Mid-upper arm, Mid-thigh, and Mid-calf, and skinfold thickness (mm) on Triceps, Mid-thigh, and Mid-calf will also be collected and recorded.

This study will not present risk that is no greater than people would typically experience in everyday activities. Anyone willing to participate in this study will be required to meet at the informational meeting in the EXS laboratory located in the Professional Studies building. This informational meeting will be held on a date to be determined.

Although this study presents less than minimal risk, there may be potential discomforts throughout the study. Participants are asked to commit to approximately an hour and a half. They will be allowed to rest, read, listen to music, or study, as long as they remain in a resting state. Participants are also asked to fast before they arrive. Participants are asked to arrive at the facility as soon as they wake up. We are willing to adjust the

schedule of the lab so that it meets their wake up times. Again, this study involves minimal risk and only measurement at resting conditions.

With risks, there are also benefits for participants in this study. The benefits of this study are: The participant involved in the study will gain knowledge of their own body composition (muscle mass and fat mass). Indeed there is an association of higher fat mass with risks for cardiovascular disease. In addition, volunteers will know specifically their daily Caloric resting expenditure. This is a benefit to help with proper nutrition (Caloric intake) and exercise (Caloric expenditure). These BMR measurements, if performed at a hospital setting, would be quite costly.

If there are any questions concerning this study, you may contact Chase Vaughn at 518-593-3188 or e-mail him at [chaserv Vaughn@gmail.com](mailto:chaserv Vaughn@gmail.com). Also, Dr. James Hokanson can be contacted for questions at 607-753-4964 or [james.hokanson@cortland.edu](mailto:james.hokanson@cortland.edu). For questions about research at SUNY Cortland or research subjects' rights, contact Jena Curtis, IRB Chair, Office of Research and Sponsored Programs, SUNY Cortland, at 607-753-2079.

The participation in this study is voluntary. If a participant refuses to participate, it will not result in a penalty of any sort. The Participant may withdraw from the study at any time.

**I \_\_\_\_\_ have read the description of the project for which this consent is requested, I understand my rights and hereby consent to participate in this study.**

\_\_\_\_\_

## Appendix B

### Arrival Script: Day One

Hello. First I would like to thank you for participating in my study. Today is the first of two days in which we are going to take measurements to see the effect that skeletal muscle mass has on basal metabolic rate.

Before we begin today's session I would like to review what we will be doing. You may ask questions at any time. I will be taking a variety of measurements to obtain data that will be used in my study. The first measurements I will be taking are height and weight. I will then begin taking circumference measurements at three sites. These sites include the mid-upper arm, mid-thigh, and mid-calf. These measurements will be taken using a flexible yet inelastic tape measure. I will then take skin-fold measurements at three sites. These sites will include mid-upper arm, mid-thigh, and mid-calf. All skin-fold measurements will be taken on the right side of the body using a Lange Caliper skin fold device. Do you have any questions about the measurement of these three sites? If you are uncomfortable with any of the measurements, you may ask to not participate in the study and all data will be void.

Today when you are done, I will give you a sheet with pre-test guidelines that you must follow prior to measuring your basal metabolic rate.

Once again, I would like to thank you for your time and participating in my study. I appreciate it. If you have any questions based on your results from this study, I can email them upon request. Any questions before we begin? Great, let's get started



## Appendix C

### Pre-Test Guidelines for Basal Metabolic Rate Assessment

Each participant must follow these pre-test guidelines exactly to ensure accurate readings across subjects. If participant fails to meet the pre-test guidelines the first time, they will be asked to return a different day. If the participant fails to meet the pre-test guidelines more than once, they may be dropped from the study.

1. No Physical activity 12 hours prior to testing.
2. Minimum of 10 hour fasting period.
3. No nicotine 12 hours prior to testing.
4. No caffeine 12 hours prior to testing.
5. Must urinate at least once prior to testing.
6. Subject must show up between the hours of 7:00am-8:30am on scheduled date of test.
7. Subject is allowed a 20 minute resting period prior to testing.

## Appendix D:

## Participant Basal Metabolic Rate Pre-Assessment Questionnaire and Agreement

Please read and answer the following questions on the line provided. Once you have completed the following questions, please read and sign at the bottom of the page.

1. How old are you? \_\_\_\_\_
2. What is your ethnicity? \_\_\_\_\_
  - a. African American
  - b. Asian
  - c. White
  - d. Hispanic
  - e. Other
3. Do you work out approximately 10 hours per week? \_\_\_\_\_
4. What type of training do you prefer?
  - a. Resistance Training
  - b. Aerobic Training
  - c. Combination of the two types mentioned above

**I \_\_\_\_\_ have followed the pre-test guidelines and answered the previous questions honestly. I understand that if pre-test guidelines were not followed, the assessment of my basal metabolic rate may be affected.**

**I have read the description of the project for which this consent is requested, I understand my rights and hereby consent to further participate in this study.**

\_\_\_\_\_  
**Signature**

\_\_\_\_\_  
**Date**

## Appendix E

### Arrival Script: Day Two

Hello. First I would like to thank you for participating in my study. Today is the second day in which we are going to take measurements to see the effect that skeletal muscle mass has on basal metabolic rate.

Before we begin today's session, I would like you to review the pre-test guidelines that we discussed in our first meeting. Have you followed these guidelines prior to arriving at the facility today? Next I would like you to review the informed consent and the Participant Pre-test Agreement (APPENDIX C), upon reviewing, please sign. Once completed, I will begin taking a variety of measurements to obtain data to use in my study.

You will be given a 20 minute resting period on a table in the lab. This 20 minute resting time includes the reading of this form and any questions you may need answered. You will be in the supine position, it is important that you stay awake and not fall asleep.

Once your 20 minutes rest period is completed, I will begin the process of assessing your basal metabolic rate. Your BMR will be tested by using indirect calorimetry. This method will calculate your  $VO_2$  and  $VCO_2$ , also known as a respiratory exchange ratio. These values will then be converted into Kcals to determine your basal metabolic rate, or how many calories you burn at rest.

First you will lie down on your back, placing your head in the canopy. You will have approximately 5 minutes to get accustomed to the surroundings before your test begins. Breathe as you would normally and try to remain calm but do not fall asleep. You will lie in

this position for approximately 15 minutes or until steady state has been obtained. I will alert you when the test has concluded.

Once again, I would like to thank you for your time and participating in my study. I appreciate it. If you have any questions based on your results from this study, I can email them upon request. Any questions before we begin? Great, let's get started.

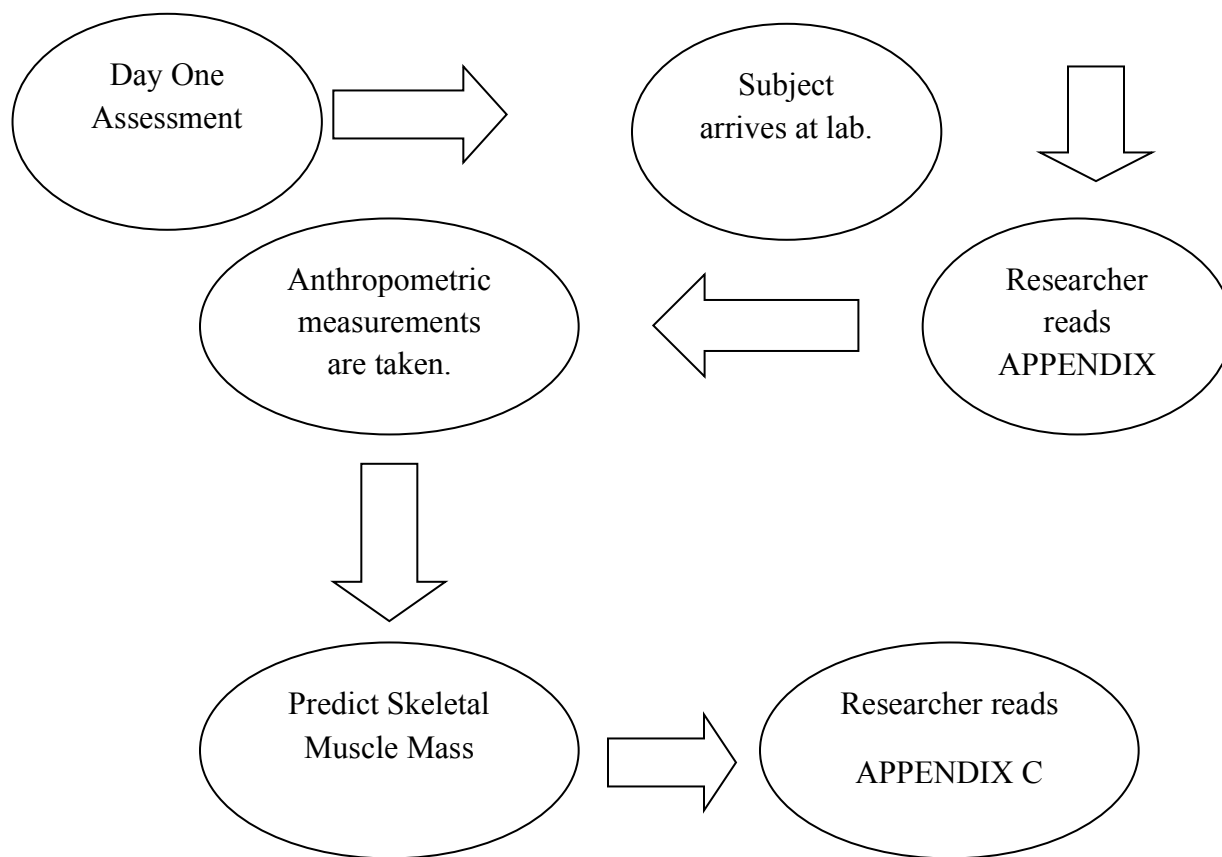
## Appendix F

## Subject Physical Characteristics and Body-Composition Measurements

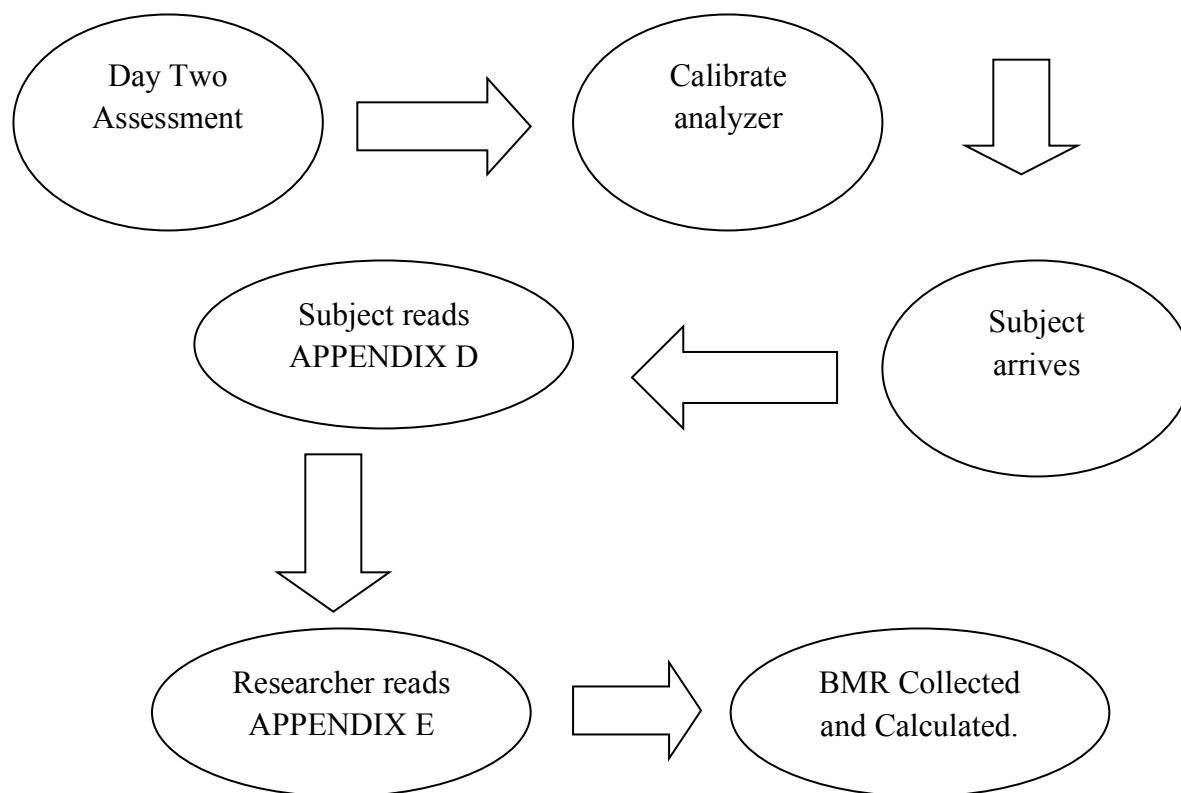
Age (Years)	
Body Weight (kg)	
Height (cm)	
BMI (kg/m <sup>2</sup> )	
Body Fat %	
Race	African American- Asian- White- Hispanic- Other-
Circumference (cm)	Arm - Thigh- Calf-
Skinfold Thickness (mm)	Triceps- Mid-thigh- Mid-calf-
Corrected circumferences (cm)	Corrected Arm Girth- Corrected Thigh Girth- Corrected Calf Girth-
Skeletal Muscle Mass (kg)	

## Appendix G

## Matrix

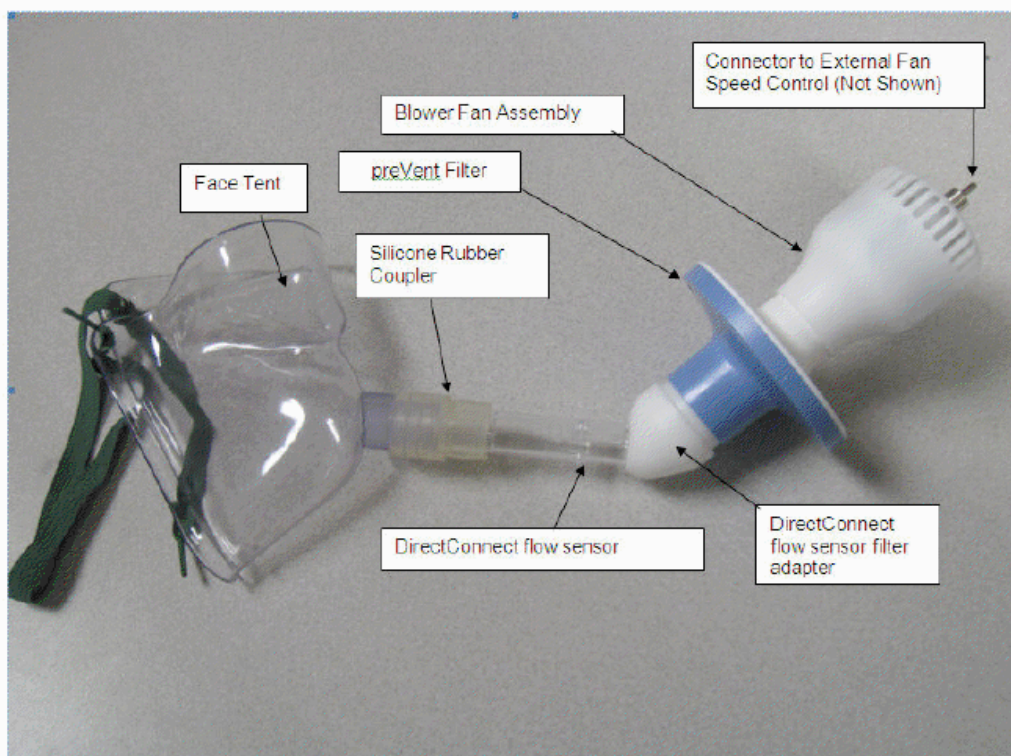


Appendix H  
Matrix



14. Plug the umbilical clip into the flow sensor
15. Connect the subject to the canopy.
16. Turn on the fan. Adjust the fan speed on the Fan Speed Controller to maximize the CO<sub>2</sub> displayed on the PWave display. A minimum of a 2% difference is recommended. If the wave shape does not return to the baseline, then your fan speed may be too slow. If the wave shape returns to baseline and stays there for over a second, your fan speed may be too fast.
17. Close the PWave dialog.
18. Click Start on the Test Pad. The data begins updating and will continue updating with each breath.
19. Once the test is complete, click Stop.

**Note:** To ensure the accuracy of the data, testing should be kept to less than 90 minutes under any one patient information entry. If a longer period of data collection is desired, the gas analyzer should be recalibrated every 90 minutes.



Setup with Face Tent

**\*\*Each mouthpiece will be cleaned before every participant.**



## Appendix I

## SCRIPT

Dear EXS 397 students,

Chase Vaughn is a graduate student in the Exercise Science Department. Chase is looking for EXS 397 students to volunteer to be a part of his thesis data. The title of the thesis is "The Effect of Skeletal Muscle Mass on Basal Metabolic Rate: Do Individuals With a Higher Skeletal Muscle Mass Have a Higher Basal Metabolic Rate?" As a participant in this study, you will know how much muscle mass is on your body, how many calories are burned at rest, and this will also count as an additional 10 points on your lab grade! Students who choose not to participate will have the option to write a 1-2 page paper for a 1- point total. If you are interested, please attend a short informational meeting in the Exercise Science laboratory on January 30, 2012.

## Appendix J

## E-mail to EXS 397 Students

Dear EXS 397 students,

I am a graduate student in the Exercise Science Department. I am asking for students who are enrolled in Dr. Hokanson or Dr. Buckenmeyer's EXS 397 labs to participate in my study. The name of my thesis is "The Effect of Skeletal Muscle Mass on Basal Metabolic Rate: Do Individuals With a Higher Skeletal Muscle Mass Have a Higher Basal Metabolic Rate?" As a participant in this study, you will know how much muscle mass is on your body, how many calories are burned at rest, and this will also count as an additional 10 points on your lab grade! Students who choose not to participate will have the option to write a 1-2 page paper for a 1- point total. If you are interested, please attend a short informational meeting in the Exercise Science laboratory on January, 30, 2012.

Appendix K  
IRB Approval Letter

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To: Chase Vaughn  
James Hokanson

From: Irena Vincent, Primary Reviewer on behalf of  
Institutional Review Board

Date: 1/9/2012

RE: Institutional Review Board Approval

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In accordance with SUNY Cortland's procedures for human research participant protections, the protocol referenced below has been approved for a period of one year:

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<b>Title of the study:</b>	The Effect of Skeletal Muscle Mass on Basal Metabolic Rate: Do Individuals With a Higher Skeletal Muscle Mass Have a Higher Basal Metabolic Rate?
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<b>Level of review:</b>	<b>Expedited</b>	<b>Protocol number:</b>	111207
<b>Project start date:</b>	Upon IRB approval	<b>Approval expiration date*:</b>	1/8/2013

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*\* Note: Please include the protocol expiration date to the bottom of your consent form and recruitment materials.* For more information about continuation policies and procedures, visit [www.cortland.edu/irb/Applications/continuations.html](http://www.cortland.edu/irb/Applications/continuations.html)

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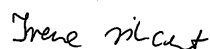
The federal Office for Research Protections (OHRP) emphasizes that investigators play a crucial role in protecting the rights and welfare of human subjects and are responsible for carrying out sound ethical research consistent with research plans approved by an IRB. Along with meeting the specific requirements of a particular research study, investigators are responsible for ongoing requirements in the conduct of approved research that include, in summary:

- obtaining and documenting informed consent from the participants and/or from a legally authorized representative prior to the individuals' participation in the research, unless these requirements have been waived by the IRB;

- obtaining prior approval from the IRB for any modifications of (or additions to) the previously approved research; this includes modifications to advertisements and other recruitment materials, changes to the informed consent or child assent, the study design and procedures, addition of research staff or student assistants, etc. (except those alterations necessary to eliminate apparent immediate hazards to subjects, which are then to be reported by email to [irb@cortland.edu](mailto:irb@cortland.edu) within three days);
- providing to the IRB prompt reports of any unanticipated problems involving risks to subjects or others;
- following the principles outlined in the Belmont Report, OHRP Policies and Procedures (Title 45, Part 46, Protection of Human Subjects), the SUNY Cortland College Handbook, and SUNY Cortland's IRB Policies and Procedures Manual;
- notifying the IRB of continued research under the approved protocol to keep the records active; and,
- maintaining records as required by the HHS regulations and NYS State law, for at least three years after completion of the study.

In the event that questions or concerns arise about research at SUNY Cortland, please contact the IRB by email [irb@cortland.edu](mailto:irb@cortland.edu) or by telephone at (607)753-2511. You may also contact a member of the IRB who possesses expertise in your discipline or methodology, visit <http://www.cortland.edu/irb/members.html> to obtain a current list of IRB members.

Sincerely,



Irena Vincent, Primary Reviewer on behalf of

SUNY Cortland

Institutional Review Board